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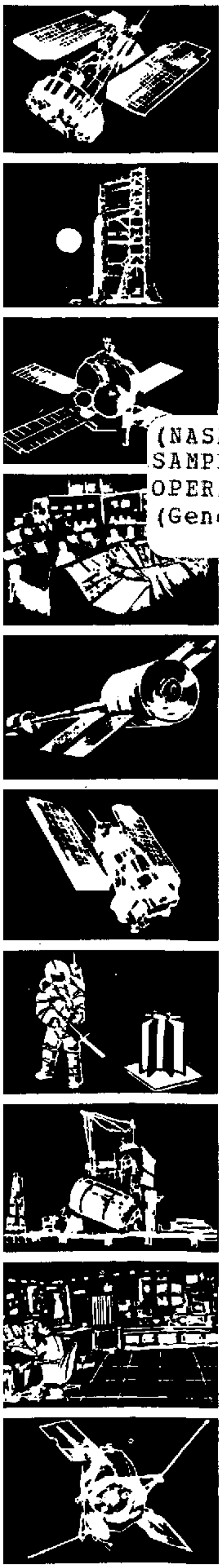

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140378

GE Report No. 74SD4208
November 1973

AUTOMATED BIOWASTE SAMPLING SYSTEM

SOLIDS SUBSYSTEM OPERATING MODEL

FINAL REPORT - PART II

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Contract NAS 1-11443

National Aeronautics and Space Administration

Lyndon B. Johnson Spacecraft Center

Houston, Texas 77058

GENERAL ELECTRIC

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Prepared By: G. L. Fogal
J. K. Mangialardi
R. E. Stauffer

General Electric Company
Space Division
Valley Forge Space Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101

GE Report No. 74SD4208
November 1973

AUTOMATED BIOWASTE SAMPLING SYSTEM

PART II - SOLIDS SUBSYSTEM

1.0 SUMMARY

The Solids Subsystem automatically provides for the collection, storage or sampling of feces and vomitus from six subjects. Verification of the subsystem design was a primary objective of the current effort. This was accomplished thru the detail design, fabrication and verification testing of an operating model of the subsystem.

2.0 BACKGROUND

With the potential of longer and longer manned space flights, it is becoming increasingly imperative that various medical experiments be performed to determine what, if any, effects long duration exposure to zero gravity and a restricted, closed environment will have on the crew. A number of biomedical problems, such as bone demineralization and microbial cross-contamination between the crewmen, are well documented in the literature for the one gravity case; however, the extent to which these conditions progress is not known for the actual flight situation.

The SKYLAB program will include a number of biomedical experiments as a start towards understanding the effects of long duration space flight. Included in the SKYLAB equipment is a biowaste sampling capability. This capability, while providing in some measure for the current SKYLAB experiments, has had to allow for a certain amount of compromise due to space and schedule requirements as well as limited capability of presently available equipment. It is intended that the Automated Biowaste Sampling System result in a system of

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Foreward

The Automated Biowaste Sampling System is composed of two major subsystems, the Urine Subsystem and the Solids Subsystem. With the exception of some shared electronics, the two subsystems are physically separate assemblies and may be operated independently or simultaneously as desired. Part II of the final report defines and describes the requirements, equipments, operation and test results for an operating model of the Solids Subsystem. Similar information for the Urine Subsystem Operating Model is contained in Part I of the final report.

sufficient flexibility to service medical experiments as presently defined, and also provide for a reasonable range of future medical experiments requirements (involving the sampling of urine, feces, and vomitus) that are not as yet defined.

Items of interest from three SKYLAB medical experiments are presented herein as a starting point for more broadly defined experiment requirements. These three experiments are: M071 Mineral Balance, M072 Bone Densitometry, and M073 Bioassay of Body Fluids. Table 2-1 lists the constituents of interest in urine, feces, and vomitus required for these three experiments. The additional items tabulated are presented to reflect the present status of anticipated future needs. This table is not to be construed to be a complete listing but only as an indication of possible future requirements.

The Solids Subsystem Operating Model described herein is a further refinement of the GE DRY-JOHN type collection and storage concept developed under previous contracts. As with previous developments, the current operating model provides for the automatic collection of solid biowastes. In addition, the current model provides for automatic sampling and for air drying of stored biowaste solids. The following sections define and describe the Solid Subsystem Operating Model design requirements, equipments, operation and verification test results.

3.0 SUBSYSTEM DEFINITION

3.1 Design Requirements

The contract work statement specifies that the Solids Subsystem Operating Model shall be sized to support a crew of six men, collect feces and vomitus, and either store and deactivate or provide as a sample the entire fecal (or

TABLE 2-1. EXPERIMENT REQUIREMENTS

ITEM	URINE	FECES	VOMITUS
Collection Measure	Yes Volume ± 2%	Yes Wet Mass ± 2%	Yes Wet Mass ± 2%
Sample Size Store Return	Yes 120 ml/24 Hr Pool Yes Yes	Yes Total/Each Yes Yes	Yes Total/Each Yes Yes
Chemicals of Interest (SKYLAB)	Sodium Potassium Magnesium Calcium Nitrogen Phosphorus Chlorine Urea Hydroxyproline Creatinine Aldosterone ADH Epinephrine Norepinephrine 17 Hydroxycorticosteroids	Potassium Magnesium Calcium Nitrogen Phosphorus Chromium	Potassium Magnesium Calcium Nitrogen Phosphorus Chromium
Additional Items of Interest That May Be Required At Some Future Time	pH Osmalality Electrolytes Angio Tension Hydro Cortisone Renin Amino Acids Microbiology Others	Sodium Chlorides Proteins Carbohydrates Cellulose Fatty Acids Microbiology Anaerobes Others	Sodium Chlorides Proteins Carbohydrates Cellulose Fatty Acids Microbiology Anaerobes Others

vomitus) mass. In addition, the subsystem must maintain itself in a clean condition between use (i.e., insure less than 1% cross-contamination between individual samples) provide for odor and contamination control, and provide for positive identification of each of the samples taken as to biowaste event (crewman ID, date, time). The operating model shall also be automated as practical to minimize crew time and sample handling. Although optimization for minimum weight, power and size is not required, the operating model must be configured to provide both a functional and attractive appearance representative of a possible flight design.

Based on the work statement design requirements and the general system concept as represented by the previous contract effort, an operating model design requirements specification was prepared (enclosed herewith as Appendix 7.1). This design specification, which defines both primary and secondary performance requirements, was used as the design control document.

3.2 Description and Operation

3.2.1 Description

Figure 3.2-1 is a photograph of the assembled subsystem; Figure 3.2-2 illustrates the subsystem block diagram. The seat, slide value, slinger and associated debris filter and phase separator, blower and filter combine to provide the collection capability. The seat serves to position the user coaxially with the slide valve assembly. The slide valve assembly isolates the storage chamber contents from ambient when the subsystem is not in use. The blower provides a source of transport air for conveying feces (or vomitus) into contact with the slinger assembly. The rotating slinger assembly in turn distributes the biowaste material in a thin relatively uniform layer,

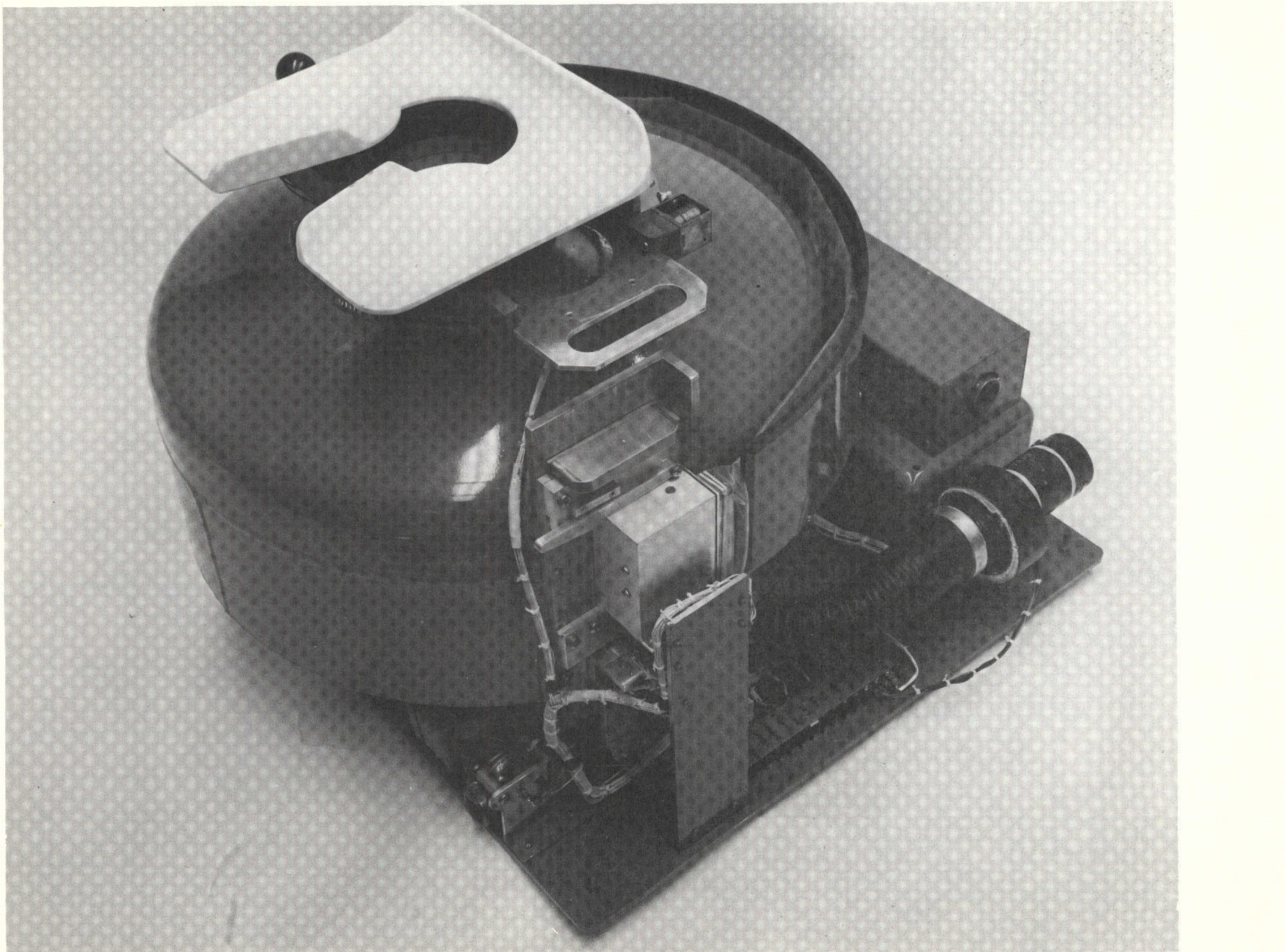


FIGURE 3.2-1. SOLIDS SUBSYSTEM OPERATING MODEL

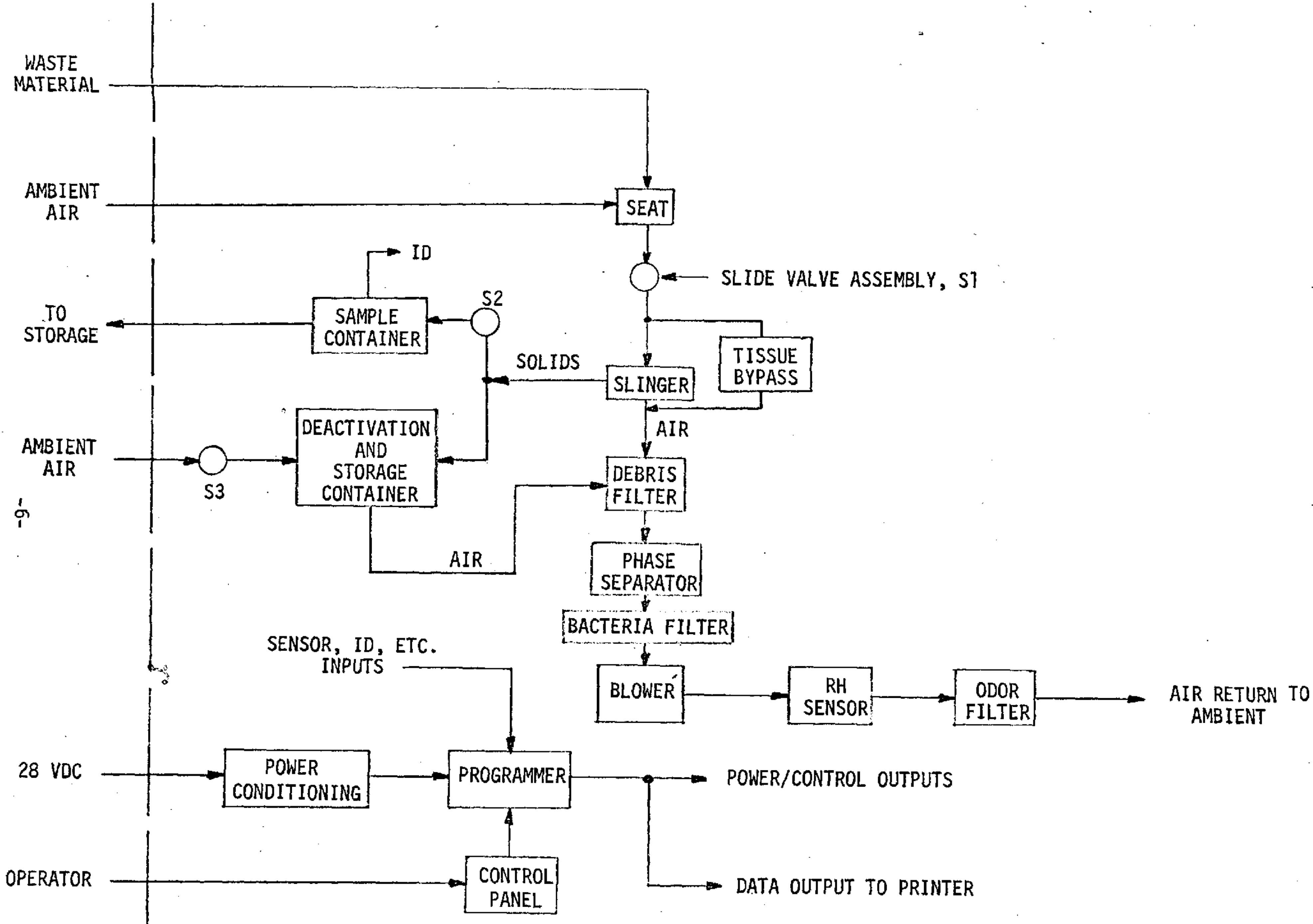


FIGURE 3.2-2. SOLIDS SUBSYSTEM BLOCK DIAGRAM

about the inner periphery of the storage container. The resulting large exposed area promotes rapid air drying (for microorganism deactivation) using ambient air circulated by the blower. A debris filter and phase separator capability are combined into the slinger assembly to prevent solid/liquid particles from leaving the storage container. Since wiping tissue will not reliably pass thru the slinger, a tissue bypass mechanism is provided. On command, the tissue bypass blocks tissue from the slinger.

If desired, the total mass of feces (or vomitus) may be collected as a sample. This is accomplished automatically by use of a sampling element which is inserted into the storage container, closely encircling the slinger. Feces or vomitus passing thru the slinger is thus "trapped" on the sampling element. The sampling element is then withdrawn into an exterior mounted sampling container, which can be removed and placed in refrigerated storage. At each use, the user ID, mission time and sample container number (if used) are recorder on an external printer.

The subsystem is designed to be operated with or independently of the Urine Subsystem. However, the operator controls for both subsystems are combined into one panel arrangement located on the top surface of the Urine Subsystem structure. Some electronic components are also shared between the two subsystems.

3.2.2 Operation

Figure 3.2-3 illustrates the subsystem operating sequence which may be divided into three operating phases, i.e., collection, sampling, deactivation. Supplemental information on system operation is also contained on the Operating Model Requirements Specification (Section 3.1.1.2.4 of Appendix 7.1) and in the Operating Instructions (Appendix 7.3).

INITIATE COLLECTION, SAMPLING SEQUENCE
(POWER ON; POWER CONDITIONING, PROGRAMMER ACTIVATED)

INSTALL SAMPLE CONTAINER (OPTIONAL)
SET SUBJECT ID SELECTOR SWITCH
OPEN INLET VALVE TO SAMPLE CONTAINER (OPTIONAL)
ACTUATE FECES START SWITCH
OPEN SLIDE VALVE: BLOWER AND SLINGER ASSEMBLY
MOTORS* AND SENSOR ELECTRONICS ACTIVATED
USER SEATED
USER DEFECATES
SAMPLE COLLECTED (OR DISTRIBUTED FOR AIR DRYING)
ACTUATE TISSUE BYPASS SWITCH
USER ID, TIME, SAMPLE CONTAINER DATA TO PRINTER
USER WIPES
CLOSE SLIDE VALVE
REMOVE SAMPLE CONTAINER
AIR DRYING (DEACTIVATION)
RH SENSOR SIGNAL (LOW RH); BLOWER AND SLINGER ASSEMBLY MOTORS OFF
TIME DELAY (1 HOUR)
AIR DRYING; BLOWER AND SLINGER ASSEMBLY MOTORS ON
RH SENSOR OR ELAPSED TIME SIGNAL; BLOWER AND SLINGER
ASSEMBLY MOTORS OFF

CONTINUE ONE HOUR OFF, ON AS REQUIRED AIR DRY CYCLES

READY FOR NEXT USER

*DEPENDING ON DRYING CYCLE ACTIVITY, BLOWER AND SLINGER ASSEMBLY MOTORS MAY ALREADY BE OPERATING

FIGURE 3.2-3. OPERATING SEQUENCE

3.2.2.1 Collection

The function of this operating phase is to collect and transmit feces (or vomitus) to the storage container for deactivation or to the sampling element for subsequent refrigerated storage. After actuating the power ON switch, ID selector switch and START switch, the cycle sequence may be started by manually opening the slide valve. This action turns on the blower and slinger motors via an interlocking position switch. Thus transport airflow is into the storage container as the valve is opened, preventing possible odor or debris flow to ambient from the storage container. The user is then seated.

At defecation, transport air, which is radially drawn into the transport tube (part of slide valve assembly) via an air gap under the bottom edge of the seat, conveys the feces "down" thru the transport tube and into the slinger. The rotating slinger then shreds and projects the resulting particles radially outward to form a thin layer around the inner periphery of the storage container. Simultaneously, the debris filter and phase separator, which are integral with and rotate with the slinger, prevent any solid or liquid particles in the transport airflow from continuing downstream (to clog the bacteria filter).

When defecation is complete, the user actuates the TISSUE BYPASS switch. Actuation of the TISSUE BYPASS switch causes User ID, mission time and biowaste event data to be transferred to the external printer. Switch actuation also causes a portion of the transport tube to rotate out of position, in effect creating a shorter transport tube, and simultaneously rotating a plate into position to positively block tissue from entering the slinger. The user then may deposit wiping tissue into the transport tube, the tissue being conveyed by the transport air past the slinger and into the storage container.

The user then returns the slide valve to the closed position completing the collection cycle.

3.2.2.2 Sampling

Sampling is accomplished as an adjunct to the collection cycle. Prior to initiating the collection cycle, a sample container is installed and the manual valve isolating the sample container from the storage container is opened. The collection cycle, from the user viewpoint, then proceeds as described above. However, when the slide valve is opened, a sampling element from the sample container is automatically projected into the storage container to closely encircle the slinger. Thus at defecation, the biowaste passes thru the slinger and is trapped by the sampling element. At TISSUE BYPASS switch actuation, the sample container number is also transmitted to the external printer. When the slide valve is closed at the end of the collection cycle, the sampling element, with biowaste attached, is automatically withdrawn back into the sample container. The sample container access valve may then be closed permitting the sample container to be removed.

3.2.2.3 Deactivation

The function of the deactivation cycle is to inhibit microorganism activity in the collected biowaste. This is accomplished by air drying (See Appendix 7.5). Deactivation occurs automatically when the manual slide valve is closed. Closing the slide valve opens the drying and inlet valve and switches the blower to low airflow operation. Airflow continues until the exit air humidity is reduced to the set value. The blower and slinger are then deactivated and the drying air inlet valve closed. At approximately hourly intervals, the drying sequence is automatically reactivated for a minimum of 5 minutes or until cutoff by the humidity sensor.

3.2.3 Interlocks

The subsystem contains a number of interlock features which are designed to prevent operator error and abnormal system operation. Thus, the manually operated slide cannot be opened if the power ON switch has not been actuated and SUBJECT ID correctly set by the user. This prevents opening the storage container to ambient without a corresponding inflow of transport air and assures that the user has identified himself. This and other interlock features are noted in Appendix 7.1, Section 3.1.1.2.4 and Appendix 7.3.

4.0 EQUIPMENT DESCRIPTION

The solids subsystem consists of two main assemblies: the container assembly and the filter assembly. Both assemblies are attached to a common mounting plate which include the air drying valve and a terminal strip for electrical connections.

The container assembly includes the seat, the slide valve, the tissue bypass, the slinger assembly, the sampling mechanism, the container, and the bacteria filter. The assembly is illustrated in Figure 4.0-1.

The filter assembly consists of the air blower, the filter and the humidity transducer all mounted on a common container as previously illustrated in Figure 3.2-1. A detailed description of the significant components is given in the following subparagraphs.

4.1 Seat

The design of the seat is probably one of the most influential factors that determine the acceptability of the hardware to the user. The seat is designed to be not too large in size to minimize surface contact, but larged enough to avoid discomfort. The seat also provides a good fit with the user to avoid excessive air leakage during zero gravity operations. The air leakage would result in a non-symmetrical air flow which may impede the transport of feces. The seat is very similar to the design previously used on the Extended Life Dry John (ELDJ, AF Contract F33-615 68-C-1372), on the Super John (NASA Contract NAS-1-8064) and the Modified Hydro John (NASA Contract NAS 9-9741).

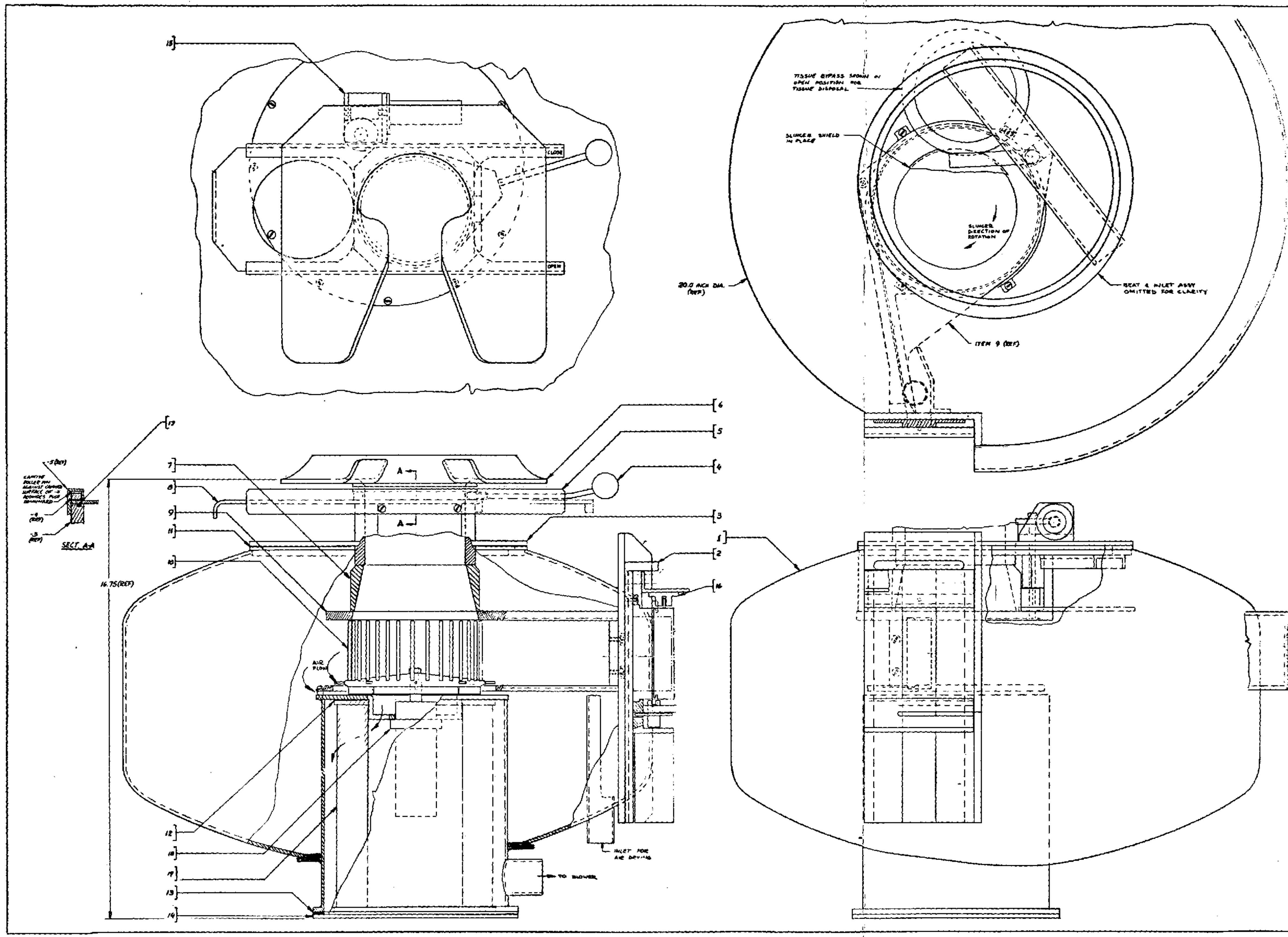


FIGURE 4.0-1

ITEM	DWG	QTY	DESCRIPTION
19	AC 6860F-4UP		FILTER, PALL CORP., GLEN COVE, L.I. N.Y.
18	102A152-10		MOTOR, SLINGER, GLOBE IND. DAYTON OHIO
17	-242		"O" RING
16	-815	1	SAMPLE I.D. ASSY
15	-814	1	DRIVE ASSY, TISSUE BYPASS
14	-813	1	COVER PLATE
13	-812 P3	1	GASKET
12	-812 P2	1	GASKET
11	-812 P1	1	GASKET
10	-811	1	SLINGER
9	-810	1	TRACK ASSY, SAMPLING ELEMENT
8	-809	1	SLIDE VALVE
7	-808	1	TISSUE BYPASS
6	-807	1	SEAT
5	-806	1	SUPPORT, SLIDE VALVE
4	-805	1	LOCK SLIDE VALVE
3	SKS -804	1	INLET ASSY
2	SK56198-803	1	SAMPLE INLET VALVE ASSY
1	SK56198-802	1	CONTAINER

GENERAL ELECTRIC

CONTAINER ASSY
SOLIDS SUBSYSTEM
ABSS

SIZE R — SK56198-825

N/A SK56198-801

The configuration has been modified in order to adapt the system to female use. The front portion of the seat has been cut out to facilitate the positioning of the urinal for female use. This design is presently undergoing extensive testing by male and female users on ground and in zero "g" trajectory flights.

The seat provides a relatively large opening for the passage of the fecal material and disposal of sanitary wipes and toilet paper. Self-positioning is assured by means of the curvature of the front cutout for male and the urinal for females which controls lateral positioning and a gentle back ramp which controls the forward-aft position. The position of this ramp is based on the relatively fixed distance between the coccyx and the anus so that when the "tail bone" is comfortably near the curved section, the anus will be in line with the center of the feces receptacle.

4.2 Slide Valve Assembly

The basic function of the slide valve assembly is to isolate the storage container from direct access to ambient. In addition, the slide valve action is electrically interlocked with the blower and slinger motors so that opening the slide valve causes activation of the blower and slinger before the slide valve opens. This interlock assures that the air flow is always into the storage container when the valve is open.

The slide valve provides two additional operational interlocks: one interlock, consisting of the solenoid operated pin, prevents the opening of the valve unless the system controls switch has been energized.

The other interlock is provided by the physical position of the slide valve itself which when closed prevents the opening of the sample valve on the side of the container. The side valve should be opened if needed only when the system is being used.

The design of the valve is basically the same as used on past programs except for a significant simplification in the mechanism that locks the slide valve in place.

The assembly consists basically of two housings, split by a movable valve plate which is manually operated to an open or closed position. The lower housing with the seal forming part of the transport tube is connected to the storage container via a gasketed joint. The upper housing is connected to the seat by means of an adapter or transport tube. The adapter contains the orifices for the air flow required to separate and transport the stool into the container.

The locking mechanism consists of a spacer plate with two ramps riding against needle like bearings. When the spacer plate is rotated by means of the black knobbed handle to the back position the ramps cause the plate to move down increasing the compression on the sliding plate to the point where the sliding plate is actually jammed in place. When the handle is moved to the unlock position the ramp is moved away from the bearing so that the spacer plate can move up and free the slide valve. The total swing to lock or unlock the valve is about 30°. The operation is relatively effortless and minimizes the wear in the "O" ring seal.

4.3 Tissue Bypass

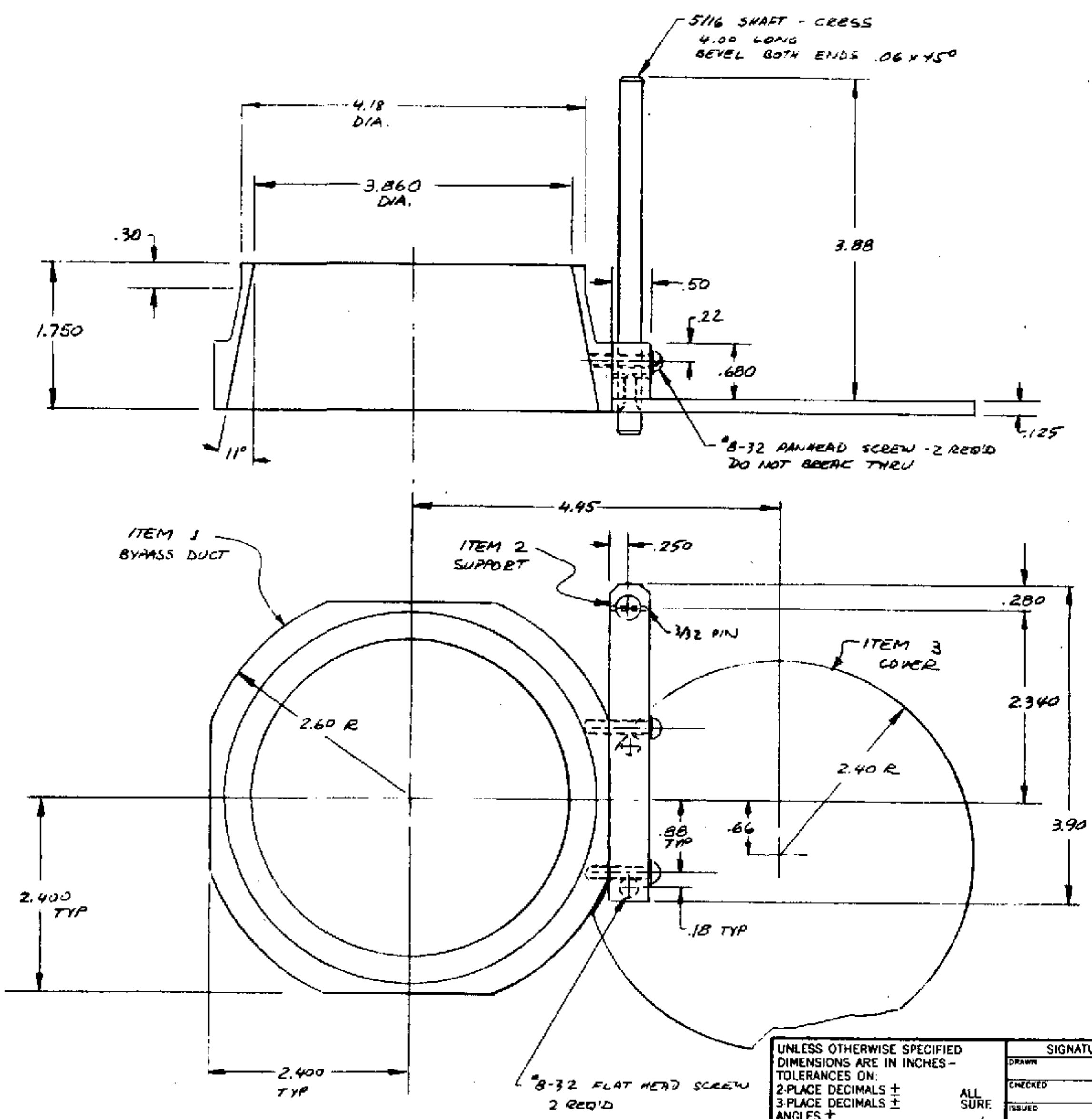
The tissue bypass is a feature which has been made necessary by the addition of the sample collection mechanism. The bypass is designed to prevent wipes or sanitary napkins from getting into the slinger by providing an alternate flow path above and around the slinger. This has been accomplished by making the lower section of the air transport tube immediately above the slinger a separate component capable of being rotated by an external motor located immediately below and behind the seat.

During defecation the transport tube leads into the slinger in the same manner as in any of the Dry-John type systems previously built and tested.

When the user is ready to drop the toilet tissue, the tissue bypass switch is energized. Powered by the external motor, the lower section of the transport tube rotates to a position leaving the cover, see item 3 in Figure 4.3-1, over the slinger and a gap where part of the transport tube was. The tissue will flow through this gap into the storage compartment. The bypass is returned to its normal configuration when the slide valve is closed which indicates no further use of the equipment.

The tissue bypass parts are made of aluminum alloy and tufram coated to add corrosion resistance and a teflon like finish.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON:
2-PLACE DECIMALS ±
3-PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF. ✓

MATERIAL - AL. ALLOY 6061-T6

SIGNATURES: DRAWN / CHECKED / ISSUED / ENGRG / MFG / MATLS

GENERAL ELECTRIC
DEPT LOC

TISSUE BYPASS
ABSS

SIZE C | CODE IDENT NO. | SK56198-808
SCALE = | SHEET

FIGURE 4.3-1

The driving mechanism consists of a motor, globe part number 168A105-3, coupled to the bypass shaft through a worm and wheel -- the angular displacement is controlled by limit switches.

4.4 Slinger Assembly

The slinger assembly consists of a rotating slinger plate, a drive motor, and supporting structure. The slinger shown in Figure 4.4-1 separates the feces from the transport air by accelerating the fecal material outward to form a thin layer around the inner periphery of the storage container. This same slinger design with minor variations has been used and tested for several years in many NASA sponsored programs. The slinger is made from aluminum alloy and tufram coated to minimize adhesion of fecal material. The slinger is provided with stainless steel tines for the shredding action on one side (facing the inlet) and with a few radial tines at the outer rim to help maintain the face of the filter free from paper or loose dried feces.

The underside of the slinger facing the support structure incorporates eight radial vanes to further assist in preventing the flow of any liquid or solids into the air return filter. The slinger is operated at a speed of approximately 2,000 rpm to obtain maximum spread over the storage container inner wall.

The supporting structure shown in Figure 4.0-1 has many functions: it houses the facteria filter; it is a return duct for the air flow; it houses the motor driving the slinger; it provides the sealed interfaces with the storage container, the electrical connection and the air duct; it also supports the lower track of the sampling mechanism.

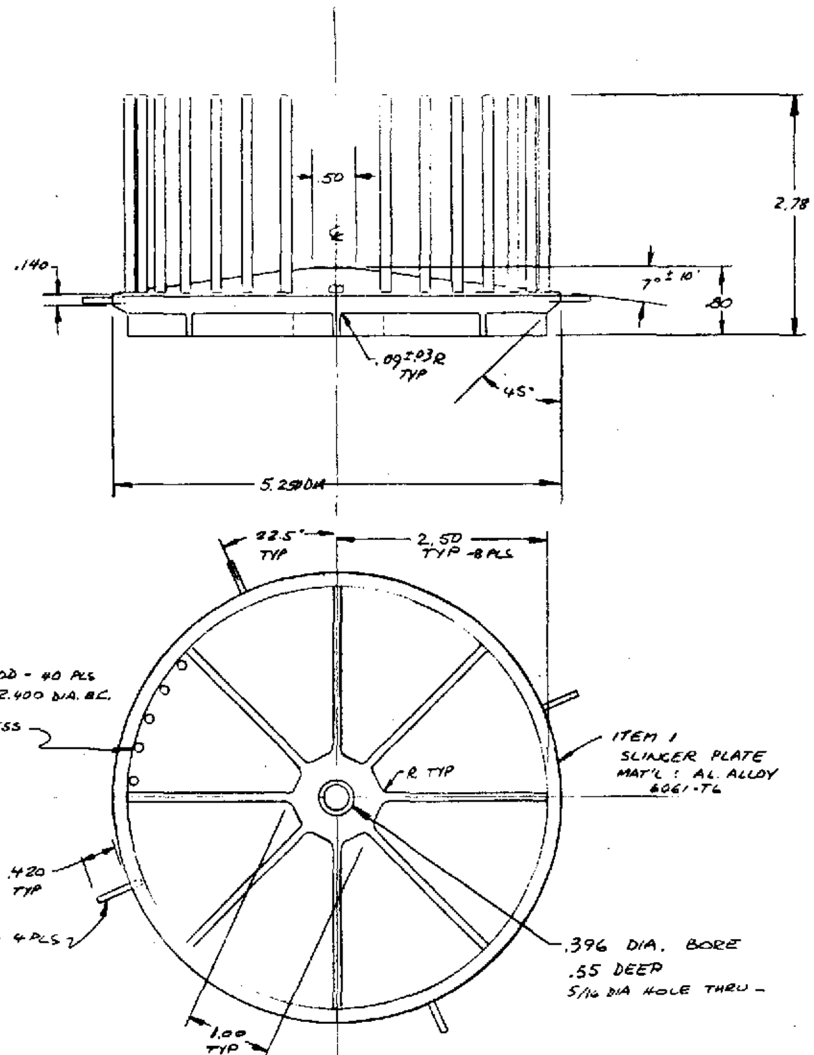


FIG. 4.4-1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES –
TOLERANCES ON:
2-PLACE DECIMALS ± .02
3-PLACE DECIMALS ± .005
ANGLES ± 1°
FRACTIONS ±
ALL SURF. 125 √

MATERIAL –

SIGNATURES	DAY	MO	YR
DRAWN Mangalo	27	5	23
CHECKED			
ISSUED			
ENGRG			
MFG			
MATLS			

GENERAL ELECTRIC
DEPT LOC

SLINGER
SOLIDS SUBSYSTEM
ABSS

SIZE C CODE IDENT NO. SK 56198-811

SCALE FULL SHEET

The motor is a 27 V.D.C. permanent magnet planetary gear unit, globe part number 102A152-10. The motor is operated at rated voltage during the deferation cycle, and at reduced voltage during the drying cycle.

4.5 Storage Container

The storage container provides the outer surface for the collection and drying of the feces. The container is sufficiently large to ensure a spread of the feces over a large surface area. In addition to providing a storage volume for fecal solids, trash and used tissues, the storage container provides a physical support for the remainder of the system equipments. This eliminates the need for support structure and the associated weight penalty and added complexity. Physically, the storage container is an aluminum oblate spheroid shell fabricated from standard ASME flanged and dished heads welded flange to flange at the equator line. This design has been successfully used on previous waste management programs and offers the advantage of minimum cost and simplicity.

The container has two wide flanged openings at the top and bottom. The top opening is used for attachment of the slide valve and seat assembly, the lower opening is used for attachment of the slinger assembly. On the left side, the smooth cylindrical section of the container is interrupted by the attachment of the sample slide valve. Immediately below the sample slide valve is located the inlet port for the air drying cycle.

The overall size of the container is approximately 20 inch diameter X 12 inch high and has a storage capacity adequate for a 6 man view - 28 day mission.

4.6 Sample Container

The ABSS provides for the collection of a total sample whenever required. This is accomplished, on command, after installing the sample container and opening the slide valve on the side of the container. A special collecting strip is automatically driven by means of tracks around the slinger and intercepts whatever material is carried by air flow through the slinger. The strip is automatically returned to the container after use. The con-trainer has a protruding tab with a series of holes which in conjunction with a set of 12 sensors permanently installed on the equipment correlate the serial number of the container to the user.

The basic design of the sample container is shown in figure 4.6-1. It consists of a housing with the drive mechanism, the collecting strip, and the sleeving covering the collecting strip.

The housing is made of aluminum alloy in the shape of a hollow box approxi-mately 2" x 3" x 4" with a sliding gage forming the inlet. The gate is shown in the open configuration in figure 4.6-1. The top of the gate is pressed into a hook which slides around a pin on the sampling valve when the container is installed. When the sampling valve is pulled up to the "open" configuration, the gate moves up with it thus allowing the unobstructed feeding of the collecting strip into the container assembly. The box has a flanged rectangular outlet at 90° from the gate. The outlet provides the means of attachment for the flexible sleeving.

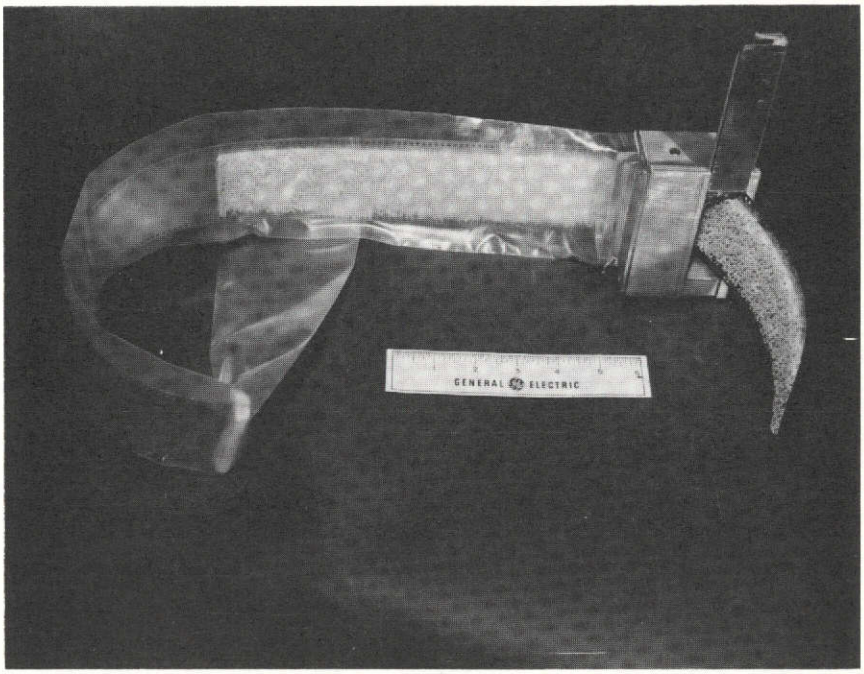


FIGURE 4.6-1. SAMPLE CONTAINER ASSEMBLY

The collecting strip is made from stainless steel foil approximately .006 inch thick. The strip has a normal width of 2.50 inches and a length of 28 inches with perforations close to the edges along the full length of the part. The perforations are used to mesh the strip with a set of sprockets inside the box. The sprockets drive the strip in and out of the container assembly. The portion of the strip which surrounds the slinger when driven in place is lined with a layer of foam material with wide open pores. The foam is needed for the retention of material of relatively liquid consistency. The other end of the strip is fitted with a teflon block which prevents the sharp edges of the strip from cutting into the sleeving and functions as a stop preventing the strip from disengaging from the sprockets in case of controls failure at the end of the cycle.

The flexible sleeving is required to enclose the strip in sterile conditions prior to use and to protect the collected sample after use. Teflon appears to be the only material which will meet the low (-100°F) temperature requirement for the subsequent freezing of the sample, without leething extraneous materials into the sample. In the operating model teflon has been replaced with polyethelyne.

4.7 Bacteria Filter

The purpose of the bacteria filter is to prevent any solid particles from escaping to ambient through the air recirculation loop. The filter has a removal rating of 98% for particles size of .008 micron and 100% for particles size of .08 micron. This indicates that the filter can retain bacteria and even viruses. This rating applies only if the filter operates with air rather than liquids. The filter material has been specially selected for operation in a moist atmosphere.

The filter has a surface area of 10.8 ft^2 pleated into a cylindrical shape 6" O.D. x 3.5" I.D. x 8.06" long. The relatively large surface permits a 30 CFM of air flow with a minimum of pressure drop below .25 inch of water.

The filter, part number AC-6860F-4UP, us made by Aircraft Porous Media, Glen Cove, L.I., N.Y. The filter is not part of the manufacturer standard stock. It is basically designed for special applications with high air flow. It was used in the system in lieu of the more standard sizes because of the low pressure drop requirements and the convenient geometrical size which is most compatible with the slinger, slinger motor and air ducting configuration.

4.8 Odor Filter

The odor filter consists of about 4 lbs. of Purafil pellets packed between the blower and the humidity transducer. The function is to remove the odors which are commonly associated with the use of this type of equipment and, in addition, any odors which emanate from the container during the air drying cycle.

The Purafil material has been selected over charcoal because the odor removal is accomplished by catalytic action and absorption rather than absorption only as in the case of charcoal. Both agents operate at peak efficiency under high relative humidity but whereas the charcoal filter would need to be replaced due to saturation, the Purafil pellets will continue to perform over a longer period of time due to the oxidation action of the catalist. The life of the purafil is expected to be twice that of the charcoal medium. The pressure drop through the filter is approximately 1.1 inch of water at 30 CFM and .4 inch at 10 CFM during the drying cycle. The Purafil material is made of 1/8" dia. pellets of activated aluminum impregnated with an alkali metal permanganate salt. Purafil is non-toxic, non-corrosive, non-flammable, and does not support bacterial or fungicidal action.

4.9 <u>Blower</u>

The blower provides the air flow for the operation of the solids subsystem under either operating mode, i.e., direct use or air drying.

The blower, model number B036, is manufactured by IMC Magnetics Corp., Westbury, N.Y. It is a continuous duty unit designed for operation at 28 V.D.C. Detailed information on power requirements, efficiency, size and weight is given in appendix 7.4.

The blower winding has specifically designed for 10,000 RPM operation in order to get the high flow and relatively high pressure head required at that flow. The blower is operated at lower speed by reducing the operating voltage during the drying cycle. The drying cycle requires only 10 CFM of air which can be obtained at the lower speed with a significant reduction in power requirement.

4.10 Relative Humidity Sensor

The drying of solids waste is controlled by a relative humidity transducer manufactured by the American Instrument Company, Silver Spring, Maryland. The transducer can sense humidity in the range of 10% to 99% R.H. with an accuracy of ± 3% R.H.

The transducer is used specifically to terminate the drying cycle when the relative humidity of the air circulating through the subsystem falls below 70%. The starting of the cycle is controlled on a time basis by the subsystem electrical controls regardless of the relative humidity of the circulating air.

The sensor is installed in the odor filter assembly container immediately before the air exhausts to ambient.

The sensor is identified by part no. 15-7012.

The appendix contains additional information on the physical size and performance characteristics of the unit.

4.11 Programmer

4.11.1 Description

The programmer consists of the electronic hardware used to provide interface circuitry for input and output electromechanical devices, and the logic circuitry necessary to generate the timing, control and telemetry formatting required by the subsystems. A block diagram (GE Dwg ER47D220983) shows the key functional elements in the programmer. The timing and telemetry formatting circuitry are packaged with the Urine Subsystem, GE Dwg. ER47D220980, and control signals are distributed to the Solid Subsystem, GE Dwg. ER47D220984. The control circuits are packaged with the Solid Subsystem. The circuitry is implemented with integrated circuits comprised of operational amplifiers for the linear circuits and C-MOS digital circuits for logic and signal processing. The C-MOS circuitry provides excellent noise immunity and minimal power consumption consistent with on-board space equipment design goals.

4.11.2 Programmer Inputs

The programmer inputs for the most part are digital signals derived from switches or position sensors, see paragraph 4.14; the operational sequence is determined by the manual control of the user through operation of control switches, the Slide Valve Assembly and the Sample Container Assembly. Limit switches are used to derive end of travel signals to protect the electro-mechanical devices and override switch inputs are provided for manual position control of the mechanical subsystem elements.

4.11.2.1 Programmer Input Buffer Circuits

Input buffer circuits are provided to convert the transducer output circuits into digital circuits electrically compatible with the C-MOS microcircuits.

The interface buffers consist of LM211 comparator circuits used to convert analog signals to digital signals. The operating point of the comparator is adjustable by means of a potentiometer accessible on the analog circuit board.

4.11.3 Programmer Outputs

The programmer output circuits are power stages capable of suppling drive current to relay circuits or D.C. motors. The logic signal energizes a current driver DH0006 which can deliver a peak current of 1.5 ampere and continuous current of 300 milliamperes. Since some of the motors require heavier current (at stall current conditions) some of the DH0006 power circuits are used to drive 2N2880 power transistor in an emitter follower configuration. This type output stage can deliver a peak current of 5.0 amperes.

The programmer also provides the telemetry data to the printer.

4.11.4 Frequency and Time Code Generator

The POWER ON switch applies voltage to the logic circuitry, part of which is a frequency and time code generator. This circuit consists of a series string of C-MOS digital counting circuits driven by a 455 HZ clock used to derive the programmer clock frequencies which are binary division of the 455 HZ clock. The time code generator is a series of decade counter driven by a 0.00278 HZ clock which is derived from the 455 HZ signal. The time code counter stores the time from power turn-on in increments of 0.1 hour and has a capacity of 999.9 hours. This power on time is multiplexed into the telemetry data. This circuitry is shown on GE Dwg. ER470220980 Sheet 1.

4.11.5 Solid Subsystem Electronics

The Solid Subsystem Electronics controls the following operations:

a. Feces Enable

b. Tissue By Pass

c. Feces Sample

d. Slinger and Blower Motor Control

4.11.5.1 Feces Enable Operation

The Feces Enable function is true if the user goes through the proper sequence of resetting and setting of the User ID switch and activation of the FECES START switch. The proper sequence of these signals will generate a driver signal which will release the interlock control of the S1 Slide Valve mechanism and enable the subsystem for the user. A status light is provided on the Control panel to indicate enable status. Opening of the Slide Valve will turn off the start light and turn on the blower and slinger motors. The circuitry consists of C-MOS logic gates used to derive the required logic status for the enable control.

4.11.5.2 Tissue By Pass Operation

The Tissue By Pass operation is activated by the TISSUE BY-PASS switch which energizes a solenoid to drive a deflecting plate into position. The TISSUE BY-PASS switch also initiates the print cycle described in paragraph 4.11.6. A status light is provided on the control panel to indicate tissue by-pass status. The closing of the S1 Slide Valve returns the deflecting plate to the start position.

The circuitry consists of C-MOS logic gates used to derive the required logic states for the enable control.

4.11.5.3 Feces Sample Operation

The Feces Sample operation is activated if the user goes through the proper sequence of installing a sample container, Feces Enable and opening of S1. The sample is gathered following the closing of S1. A status light is provided on the control panel to indicate sample status. The circuitry consists of C-MOS logic gates used to derive the required logic states for the sampling operation.

4.11.5.4 Slinger and Blower Motor Control

The Slinger and Blower Motor Control is activated when S1 is open, or when the humidity transducer indicates a high level or on a period basis 6 minutes every hour. This circuitry is comprised of C-MOS gates and a counter used to implement the desired motor drive signals.

4.11.6 Multiplexer and Print Control

The Multiplexer and Print Control selects the desired system data and transmitts this data to the printer. The printer generates a hold command to prevent data scrambling during the print cycle. The data is selected after the TISSUE BY PASS cycle and the FECES data format is:

FIRST LINE	User ID, Mission Time
SECOND LINE	Spare XXX, Container #

The circuitry is shown in GE Dwg. ER47D220980 Sheet 7.

4.12 Power Conditioning

4.12.1 Primary Power Requirements

The Solid Subsystem can operate from any power source that supplies $+28 \pm 2$ VDC at 10 amperes. When the equipment is operated from a laboratory power supply, the ripple on the input power lines should not exceed 100 MV. The power source should be turned on and adjusted to the proper voltage prior to activating the

POWER ON switch on the Urine/Solid Control Panel. After the POWER ON switch is activated, a visual indication is illuminated to signify that primary power is applied to the power conditioning circuitry. Should this indicator not be illuminated the POWER ON switch should be activated again and the primary power input circuit should be checked for proper voltage and/or connection to the equipment.

The +28VDC is distributed to the Solid Subsystem from the Urine Subsystem, GE Dwg. ER47D220980.

4.12.2 DC to DC Converters

A DC to DC Converter in the Urine Subsystem is used to develop the required operating voltages for the Solid Subsystem electronics (GE Dwg. ER47D220980).

A Burr Brown Model 528 is used to develop the $\pm$15VDC power supplies used for signal processing in the Solid Subsystem. The +15 VDC supply is used to develop +12 VDC and +5 VDC required to drive the logic circuits. This converter (Model 528) is capable of delivering 6.0 watts.

4.13 Printer

The printer is a Practical Automation Inc. Model CMMP-6A Be six channel machine. The circuitry consists of solid state TTL and discrete part semiconductor power output circuits. The 120 VAC 60 HZ input power is converted to secondary DC and AC voltage needed to drive the internal circuit.

The input data to the printer is binary coded decimal (4 bits per channel) and a print command and the printer output data consists of six channels of decimal numerics (0 to 9). The printer is capable of printing greater than one line/ second.

5.0 VERIFICATION TEST RESULTS

Laboratory tests were performed to verify or determine the operating performance of the ABSS solids subsystem.

5.1 Tests Conducted At The Component Level

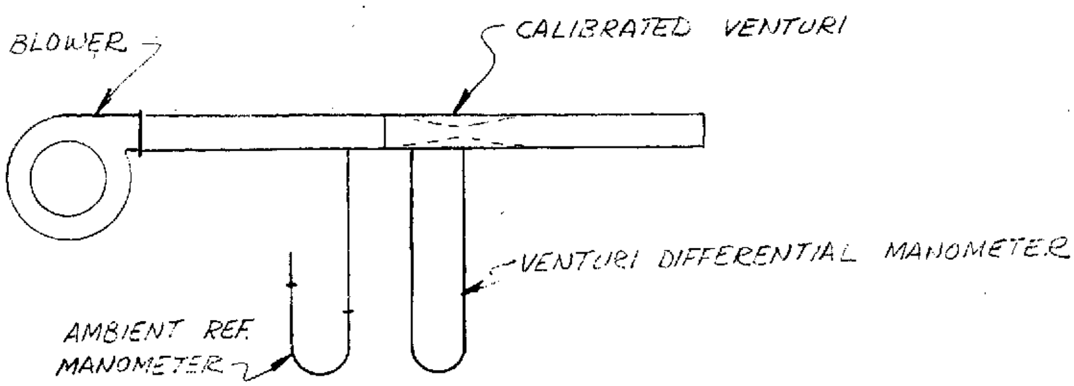
5.1.1 Transport Air Blower

Purpose of Test

Verify vendor supplied air flow and pressure drop data for the air circulation blower, part no. BD2011D-16 manufactured by IMC Magnetic Corporation, Westbury, N. Y.

Test Setup

The inlet to the blower was connected to a Venturi calibrated in the range of 0 to 50 CFM. A water manometer was connected in the adapter tube used to connect the Venturi to the blower. The blower outlet exhausted to ambient. Variations in flow rate could be obtained by blocking the air flow before entering the Venturi tube (see sketch below).



Test Results

The results of the first test run are shown in the lower curve of Figure 5.1.1. True free flow conditions could not be obtained due to the presence of the Venturi which accounts for a pressure drop of 1.5 inches of water at the "nominal" free flow. The test was repeated to measure "suction", rather than "positive" flow by locating the venturi at the inlet of the blower. Even in this case the "nominal" free flow indicated a 1.5 inches of pressure drop at the inlet of the intake line. The test indicated that there is no significant difference in performance whether the blower is operated as a suction device or an air pump. In either case the data was considerably below the vendor published performance curve. A review of the test set up showed that the input power was set at 24 V.D.C. An optical tachometer was used to measure the speed of the impeller. The speed was approximately 8,500 RPM.

The voltage was then adjusted to 27 V.D.C. The speed of the blower increased to 10,000 RPM and the air flow/pressure drop measurements were repeated. The results are plotted in the same Figure 5.1.1. The conclusion is that when operated at the proper speed the blower is more than adequate to meet the system requirements.

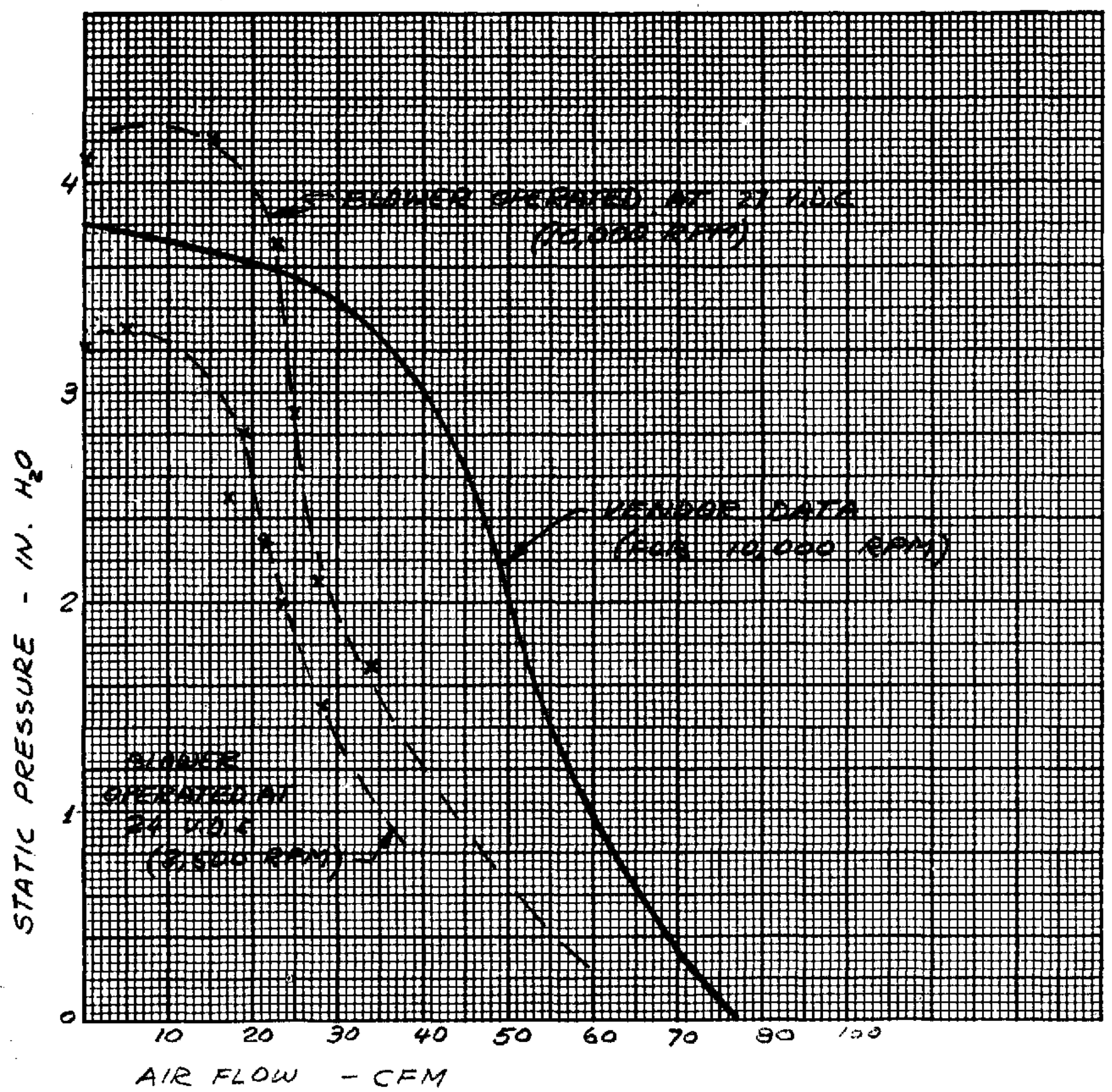


FIGURE 5.1.1 - PERFORMANCE OF IMC BLOWER
BD2011D-16.

5.1.2 Transport Air Filter (Bacteria)

Purpose of Test

Determine pressure drop for air flows from 0 to 20 CFM for the air filter, part #AC-6860F-4UP made by Aircraft Porous Media, Glen Cove, N.Y.

Test Setup

The filter with one end sealed was connected to a flow meter calibrated for air flows between 0 and 50 CFM. A water manometer was connected at the interface between the filter and the manometer so that the pressure drops measured were related only to the filter.

The air flow was produced by using shop air through a value manually adjusted to obtain the desired flow as required.

Test Results

The test results are summarized in Figure 5.1.2. The pressure drop through the filter are negligible even at the relatively high flow of 30 CFM. This is due to the large amount of filter surface area which measures 10.8 ft^2. In order to assure that the low readings were not due to leakage in the test setup down stream of the manometer the filter surface was enclosed with packing and sealed. This condition led to stalled flow and high pressure even at very low flow settings indicating that no significant leakage was present in the test setup.

5.1.3 Odor Filter

Purpose of Test

The purpose of the test was to determine the pressure drop through the odor filter for air flows ranging from 0 to 20 CFM. The filter consists of Purafil pellets packed in the filter housing with a cross sectional area of 4 x 6 inches and a depth of 5 inches.

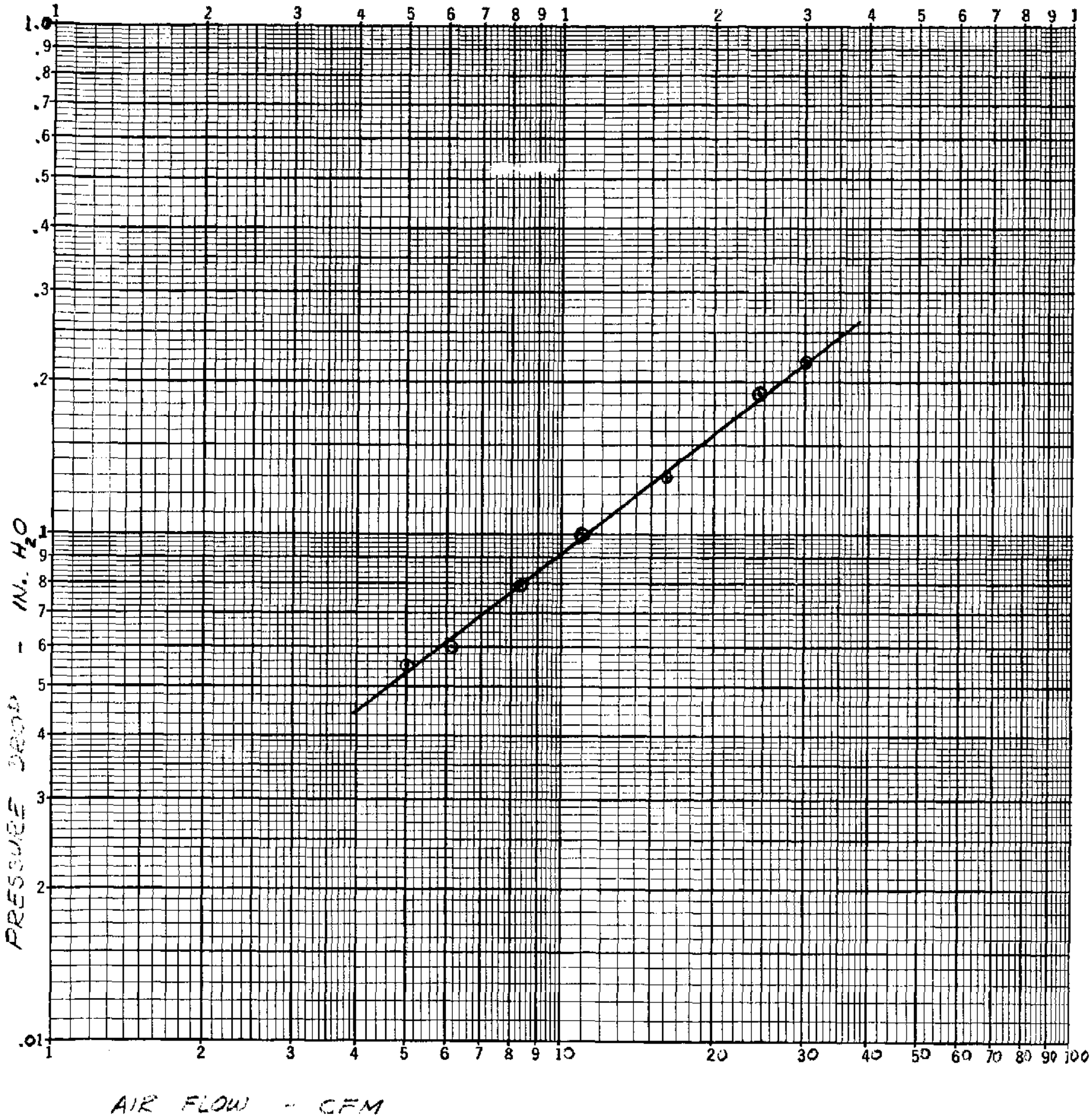


FIGURE 5.1.2 - PRESSURE DROP FOR TRANSPORT AIR FILTER, # AC-6860 F-UP

Test Setup

The test was conducted by operating the system in its final configuration and measuring the pressure drop across the filter section for various flows. The flow measurements were obtained with a Venturi attached at the ambient exhaust end of the filter assembly. The pressure drop was measured with a water manometer attached between the blower and the inlet to the Purafil pellets bed. The test was then repeated after removing the Purafil pellets.

Test Results

The test results are shown in the form of three plots in Figure 5.1.3.

Plot A shows the pressure drop through the filter assembly with the Purafil in place, i.e. total system pressure drop.

Plot B shows the pressure drops after removing the Purafil. Plot C is obtained by substracting plot A from plot B. The pressure drop for a 20 CFM flow would be 1.25 inches H_2O, a value which is consistent with other commercial filters of this type and size. The results indicates that most of the pressure drops through the system are due to the general system geometry from inlet to cabin exhaust rather than the two filters, i.e., the bacteria and odor filter which account for only 1.40 inches of water at 20 CFM. The blower as shown in paragraph 5.1.1 is capable of flowing more than 20 CFM thru the subsystem. Improvements in the filter design would not significantly affect the maximum air flow.

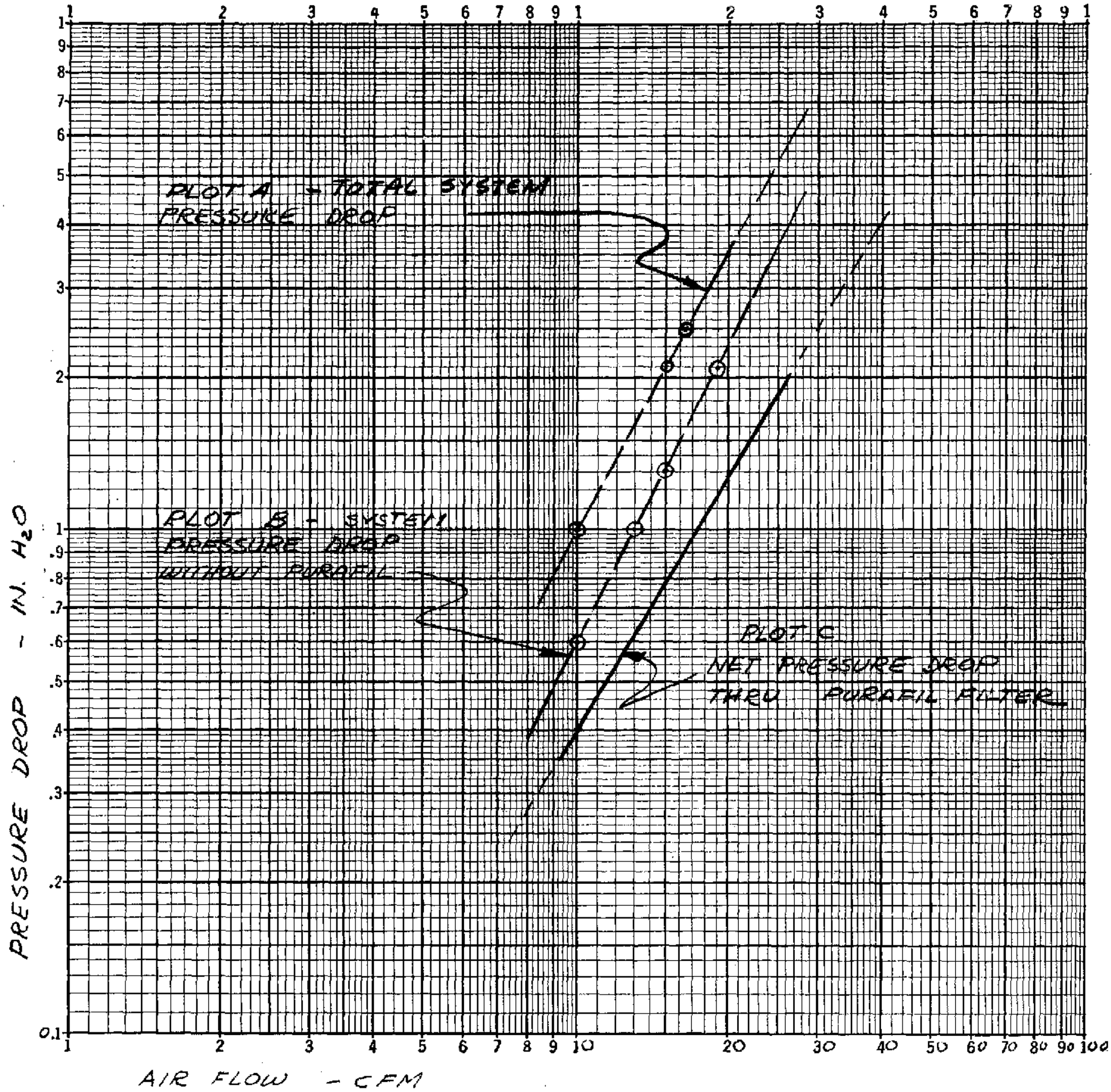


FIGURE 5.1.3 - PRESSURE DROP THROU PURAFIL FILTER

5.1.4 Slinger Assembly

Purpose of Test

Verify operation at design RPM.

Test Setup

The test setup consisted of the slinger installed in its final configuration and connected to the electrical controls for normal operation.

The speed of the slinger was measured with the same optical tachometer used for the tests described in paragraph 5.1.1.

Test Results

The rotational speed of the slinger was measured to be 2180 RPM, slightly higher than the 2000 RPM noted in the subsystem specification. Tests with several simulated feces "loadings" in excess of 100 gms showed that both the slinger speed and torque capability are more than adequate to provide satisfactory operation.

5.2 Subsystem Level Tests

5.2.1 Operational Tests

After completing all the mechanical installation and electrical interconnections the subsystem was operated through the various functions mainly for the purpose of setting limit switches and adjusting mechanisms such as those required for the tissue bypass and the solids sampler drive. All the components were found to operate satisfactorily.

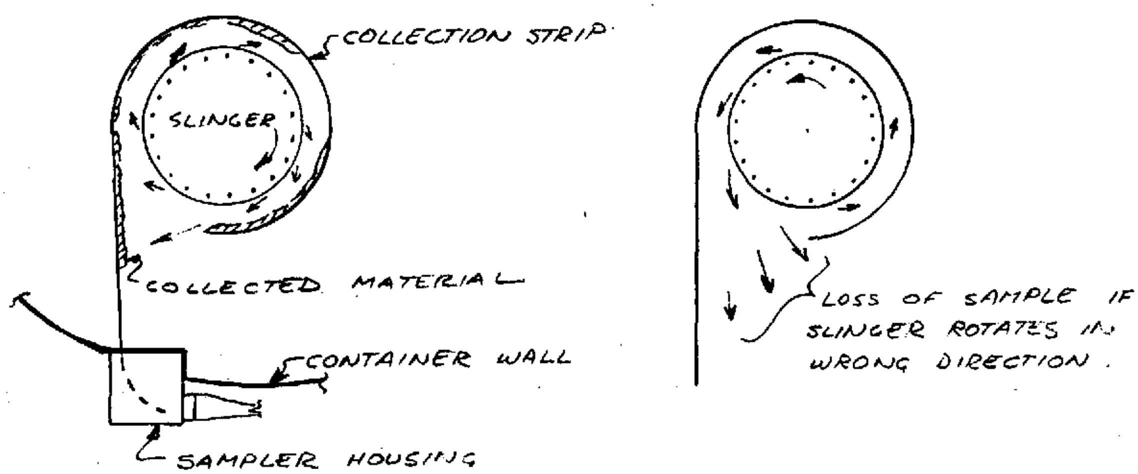
The blower and the slinger operate immediately as the slide valve is operated. The slide valve remains locked unless the "Feces Start" button is pressed, the sampling strip automatically feeds into the container around the slinger and feeds back out again when the "Tissue Bypass" button is operated.

The tissue bypass and the feeding of the sampling strip into and out of the container are accomplished in less than 10 seconds.

5.2.2 Sampling

The sampling mechanism was tested by using simulated fecal material. The simulation material consisted of a mixture of approximately 40% dry dog food, 20% peanut butter, 40% water. A total of eight sampling runs were made. The first two sampling runs were partial failure due to the wrong direction of rotation of the slinger and to peeling of the porous pad from the sample collection strip.

The design of the sample collection strip is such that 100% collection can be obtained without having the strip totally enclosing the slinger if the slinger is rotating in the right direction. This is due to the fact that the material leaves the slinger in a direction tangential to the axis of rotation as shown below.



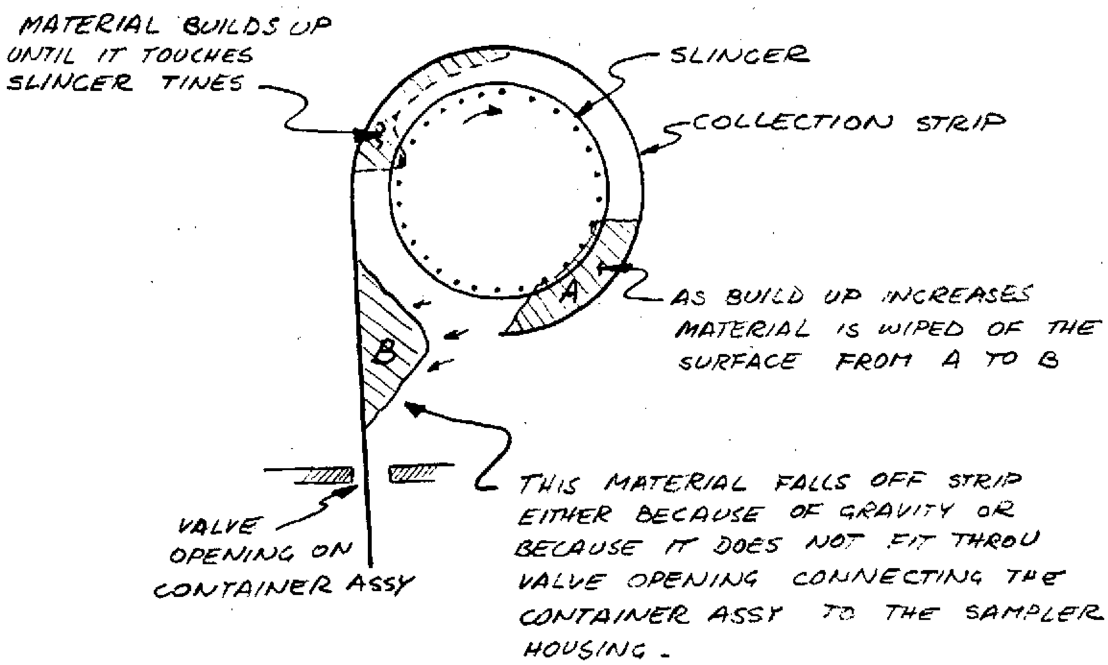
If the slinger were to be rotated in the wrong direction a significant amount of the total sample is lost. The second cause of failure was due to the partial peeling of the porous pad which had been added to the surface of the stainless steel strip to improve the retention capability of the sampling mechanism. This pad was totally ripped off during the second run. The following runs were made without the porous material and after connecting the direction of rotation of the slinger by switching the polarity of the motor leads.

A summary of the results is shown in the table below.

Table 5.1.2

Run #	Sample In gms	Sample Collected gms	Comments
1	116	23	Wrong slinger rotation.
2	100	28	" " "
3	109.3	103.5	94.5% Collection
4	100	80	80% Collection
5	113	-	Lost
6	108	104	96.3%
7	106	-	Lost
8	106	100	94.4%

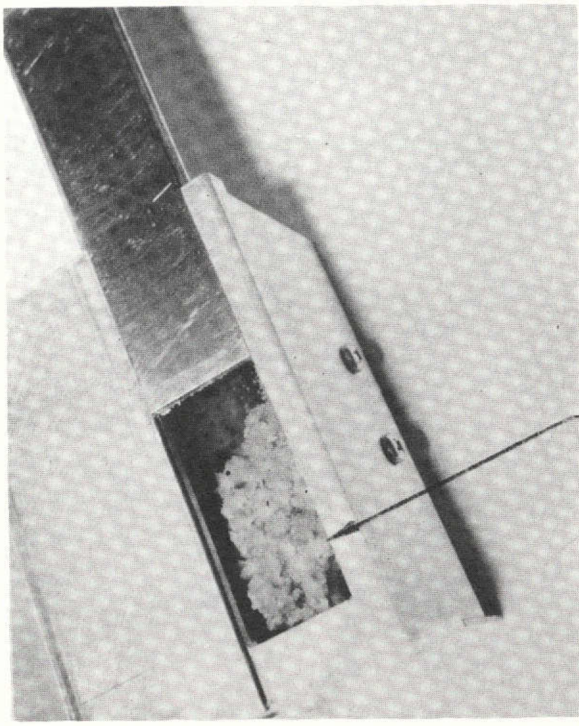
The results of test runs #5 and #7 show that no sample was collected. The failure was apparently due to the large build up of solids on a relative small section of the surface of the collection strip as opposed to a relative uniform distribution over the entire 360° collection angle. The local build up must have exceeded the clearance between the slinger and the surface of the collection strip. It was noted that the motor-slinger assembly was nearly stalled in both cases. Due to relatively poor adhesion between the simulated feces and the surface of the collection strip, the samples was eventually totally wiped off as shown below.



Although the number of test runs was relatively limited, there was sufficient evidence to draw the following conclusions:

1. The concept is feasible and can be made to work satisfactorily.
2. The distance between the slinger tines and the surface of the collection strip needs to be increased.
3. Additional development is required to improve the retension capability of the collection strip.
4. The side valve and sampler feeding mechanism operate satisfactorily.

Figure 5.2.2 shows photographs of the fecal sampler after a successful collection. The top photo (5.2.2a) shows considerable accumulation immediately beyond the sampler inlet. The accumulation is not abnormal when considering the geometry of the collecting strip: the sample is collected on the portion of the strip which ends in the sampler housing. The other end of the strip never sees any sample since it remains engaged in the sampler housing when the forward end is positioned around the slinger. Also as the sample is retrieved there is a certain amount of slippage which causes the accumulation to be a little heavier near the end of the strip. The slippage is more evident in 5.2.2b where the entire sample can be seen moved uniformily downward and partially off the collection strip. This is due to gravity and the poor wetting characteristics between the simulated fecal material and the smooth surface of the stainless steel strip.



a. CLOSE UP OF SAMPLER HOUSING AFTER SAMPLE COLLECTION

SIMULATED FECAL MATERIAL

b. COLLECTION STRIP VIEWED THROUGH POLYETHYLENE COVER

WIDTH OF COLLECTED SIMULATED SAMPLE

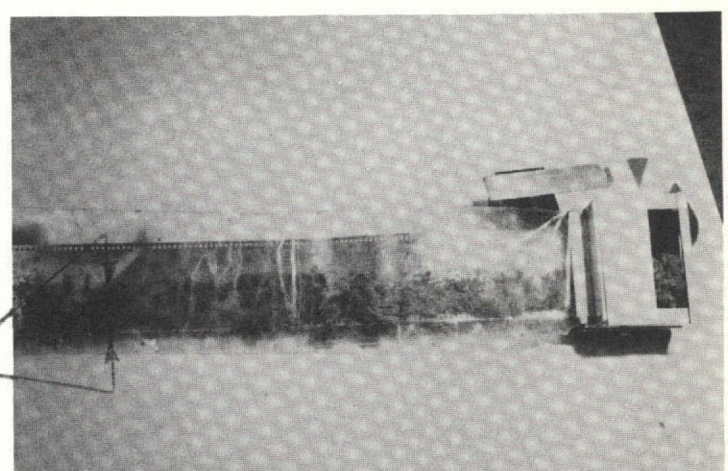
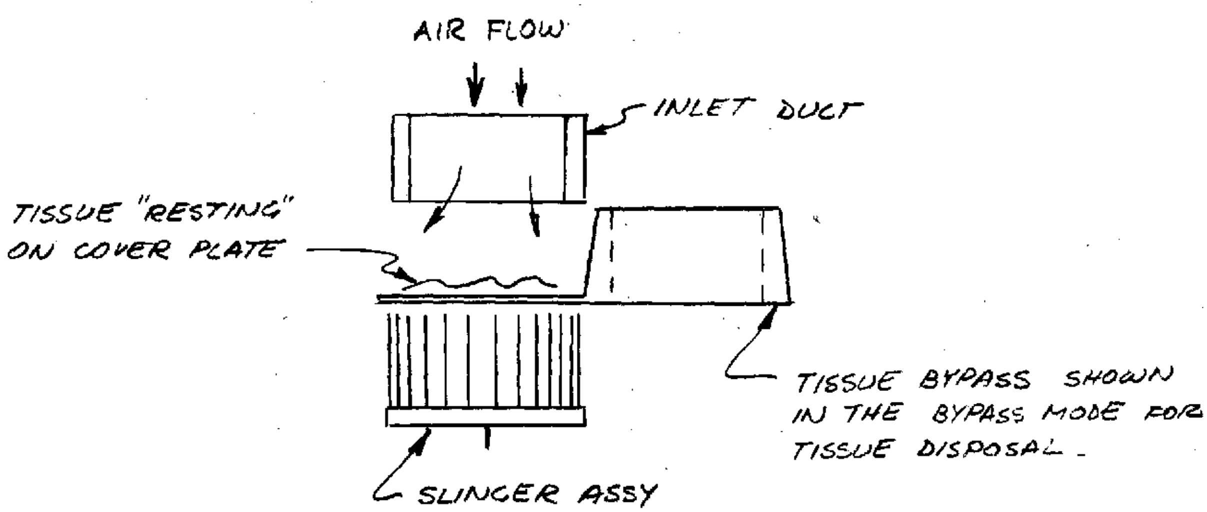


FIGURE 5.2.2 - TYPICAL DISTRIBUTION OF COLLECTED SAMPLE

5.2.3 Tissue Bypass

The operation of the tissue bypass design was tested in conjunction with the sampling tests described in the previous paragraph. After dropping the simulated stool several drops of actual toilet tissue were made. The tissues were the typical 5 1/2 x 4 1/2 loose double sheets supplied in metallic dispensers. The sheets were dropped through the inlet opening and were drawn into the container by the air flow. Some fell in the middle of the slinger cover plate and remained there. It was obvious that at least for one "g" test condition the air flow was not adequate in removing the tissue paper once the paper had settled on the plate as shown below.



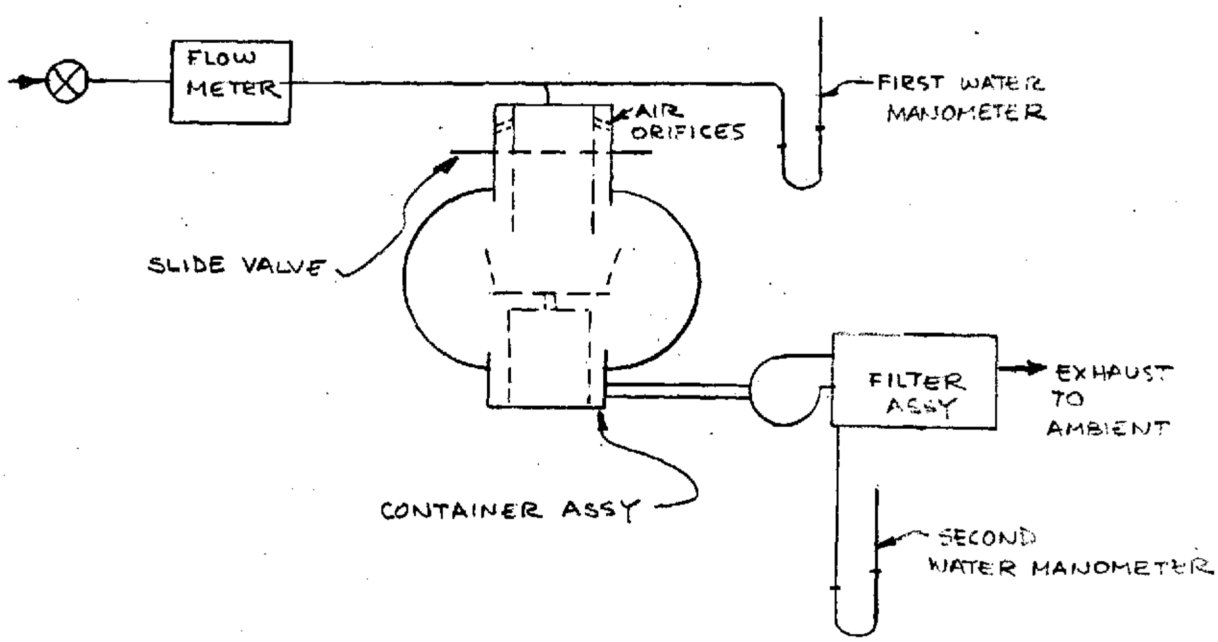
This condition may be corrected by shaping the top of the bypass plate so as to ease the sliding of the paper into the container assembly in one "g" test condition.

Also to assure reliable performance in zero "g" application the height of the tissue bypass may need to be increased.

5.2.4 Subsystem Pressure Drop

Measurements were made to determine the pressure drop at various points in the system at air flow levels up to 30 CFM.

The tests were conducted using shop air regulated by a hand valve. The air was circulated first through a flow meter then through the system which was instrumented as shown.



Since the above test setup did not account for the pressure drop through the orifices an additional test run was made with the slide valve closed and the air flowing through the orifices only as shown.

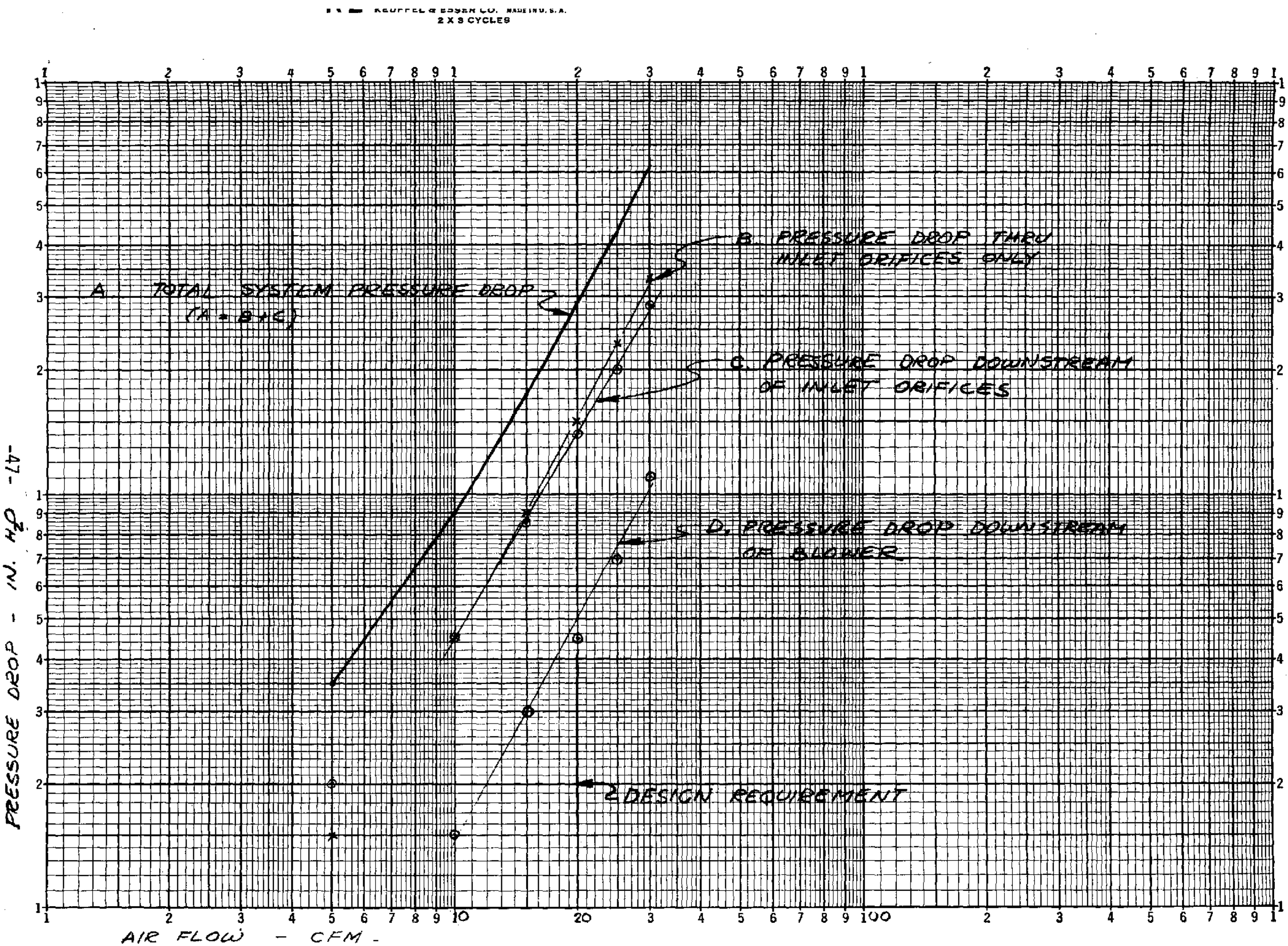


FIGURE 5.2.4 - SUBSYSTEM PRESSURE DROP VS. AIR FLOW

The results are plotted in Figure 5.2.4. It can be seen that the pressure drop through the orifices (curve B) equals or exceeds the pressure drop through the rest of the system (curve C). The results from the two tests are added to obtain curve A which represents the total drop for the solids subsystem. When combined with the data shown in Figure 5.1.2 and 5.1.3, the data shown in Figure 5.2.4 can be used to evaluate the pressure drop from the following point to point.

a) Inlet orifice

b) Bacteria filter only

c) Ducting from inlet to blower

d) Odor filter

e) Ducting from blower to ambient exit point

5.2.5 Subsystem Air Flow

The air flow through the subsystem can be obtained by combining the total pressure drop shown in curve A of Figure 5.2.4 and the air flow capability of the blower shown in Figure 5.1.1.

Direct readings of total flow through the subsystem are shown in Figure 5.1.3. The highest flow achievable was 17 CFM approximately. However this flow was based on 24 V.D.C. power input. At this lower voltage the blower operates at lower speed, see Figure 5.1.1, with consequent lower performance. The subsystem specifies an air flow of 20 CFM. The pressure drop measured for 20 CFM from Figure 5.2.4 is 2.9 inches of water. The air flow provided from Figure 5.1.1 by the blower at 2.9 inches of water is approximately 25 CFM which is in excess of subsystem requirements.

6.0 RECOMMENDATIONS

Recommendations for possible follow-on activity are in two areas; testing and incorporation of a real time mass sensing capability.

6.1 Testing

The incorporation of an automatic biowaste sampling capability plus deactivation by air drying into a DRY-JOHN type collection system represent a significant advance in automated biowaste collection and sampling. For this program, subsystem level testing was confined mainly to checkout and performance verification activity. Thus additional testing of both the air drying and sampling capabilities is needed. Briefly, a test program oriented towards use of simulated biowastes followed by live subject testing is recommended.

Results of this test activity will be extremely useful in further verifying design and operational performance in the areas of multi-man use, cross contamination and performance variation as a function of mission time.

6.2 Mass Sensor

The Solids Subsystem Operating Model does not contain an integral mass sensing capability. In lieu of mass sensing, the entire biowaste discharge is "collected" and placed in the sample container for subsequent weighing and chemical analyses. A real time mass sensor which functions automatically and does not require sampling is needed. Development of a real time mass sensor meeting the following objectives is recommended:

(a) Accommodate diarrhetic as well as normal type fecal discharges.

(b) Provide mass measurement in real time, i.e., not requiring subsequent ancillary actions.

(c) Provide automatic operation.

(d) Compatible and integratable with the GE DRY-JOHN type feces collection and storage systems.

(e) Compatible with but not requiring feces sampling.

(f) Provide measurement accuracy of $\pm$ 2%.

(g) Compatible with gravity independent operation.

7.0 APPENDICES June 1973

7.1 Design Specification

AUTOMATED BIOWASTE SAMPLING SYSTEM

FOR

MEDICAL RESEARCH

SOLIDS SUBSYSTEM OPERATING MODEL

REQUIREMENTS SPECIFICATION

CONTRACT NAS 1-11443

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

GENERAL ELECTRIC COMPANY

P. O. BOX 8555

PHILADELPHIA, PENNSYLVANIA 19101

AUTOMATED BIOWASTE SAMPLING SYSTEM

SOLIDS SUBSYSTEM OPERATING MODEL

DESIGN SPECIFICATION

1.0 SCOPE

This specification defines the performance and design requirements for the Solids Subsystem portion of the Automated Biowaste Sampling System Operating Model and establishes requirements for its design, development and test.

All contract end items of the Solids Subsystem shall conform to the requirements stated herein.

1.1 Purpose

The purpose of the Solids Subsystem Operating Model shall be to provide conceptual verification of an equipment assembly applicable to manned space flight and which automatically provides for the collection, storage and sampling of feces and vomitus from human subjects.

1.2 Definitions

For the purposes of this document, the following definitions and abbreviations shall apply:

Later

2.0 APPLICABLE DOCUMENTS

Statement of Work, as modified, Contract NAS 1-11443.

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements

3.1.1.1 Primary Performance Requirements

3.1.1.1.1 Collection Requirements

The Solids Subsystem Operating Model shall collect the total quantity of feces or vomitus voided by a human subject. Specific requirements are as follows:

a. The Operating Model shall accommodate individual defecations ranging in mass up to a maximum of 400 grams (110 grams average) or a maximum diarrhetic liquid/solid mix of 500 grams/discharge and 500 to 1200 grams/man-day.

b. The Operating Model shall accommodate a maximum vomitus liquid/solid mix of 500 grams/discharge and 1000 grams/man-day.

c. The Operating Model shall accommodate a total of 6 subjects with an average of one defecation per day per user.

3.1.1.1.2 Waste Storage

The Solids Subsystem Operating Model shall be capable of providing, at user option, integral controlled storage of feces or vomitus.

3.1.1.1.3 Sampling Requirements

The Solids Subsystem Operating Model shall be capable of providing, at user option, representative samples from each defecation or vomiting. Specific requirements are as follows:

a. Sample Container - The Operating Model shall provide individual user identified sample containers. The sample containers shall not degrade subsequent chemical or microbiological analyses or moisture content determinations.

b. Contamination - Cross contamination from sample to sample shall not exceed 1%.

3.1.1.1.4 Equipment Requirements

The Solids Subsystem Operating Model shall conform to the functional block diagram of Figure 3.1.1.1-1.

3.1.1.1.4.1 Displays

The Operating Model shall provide a visual indication of operational status.

3.1.1.1.4.2 Power Conditioning

The Operating Model shall be designed to operate on nominal 28 VDC power.

3.1.1.1.4.3 Gravity Field

The Operating Model shall be designed for gravity independent operation. However, performance will be demonstrated for normal earth gravity conditions only.

3.1.1.1.4.4 Configuration

The Operating Model shall be configured to provide both a functional and attractive appearance representative of a possible flight configuration. The Model need not be optimized for minimum size, weight or power input.

3.1.1.1.4.5 Operation

The Operating Model shall be designed for a high degree of automatic operation. Defecation preparation time shall not exceed 30 seconds. Sampling and waste storage control shall be automatic.

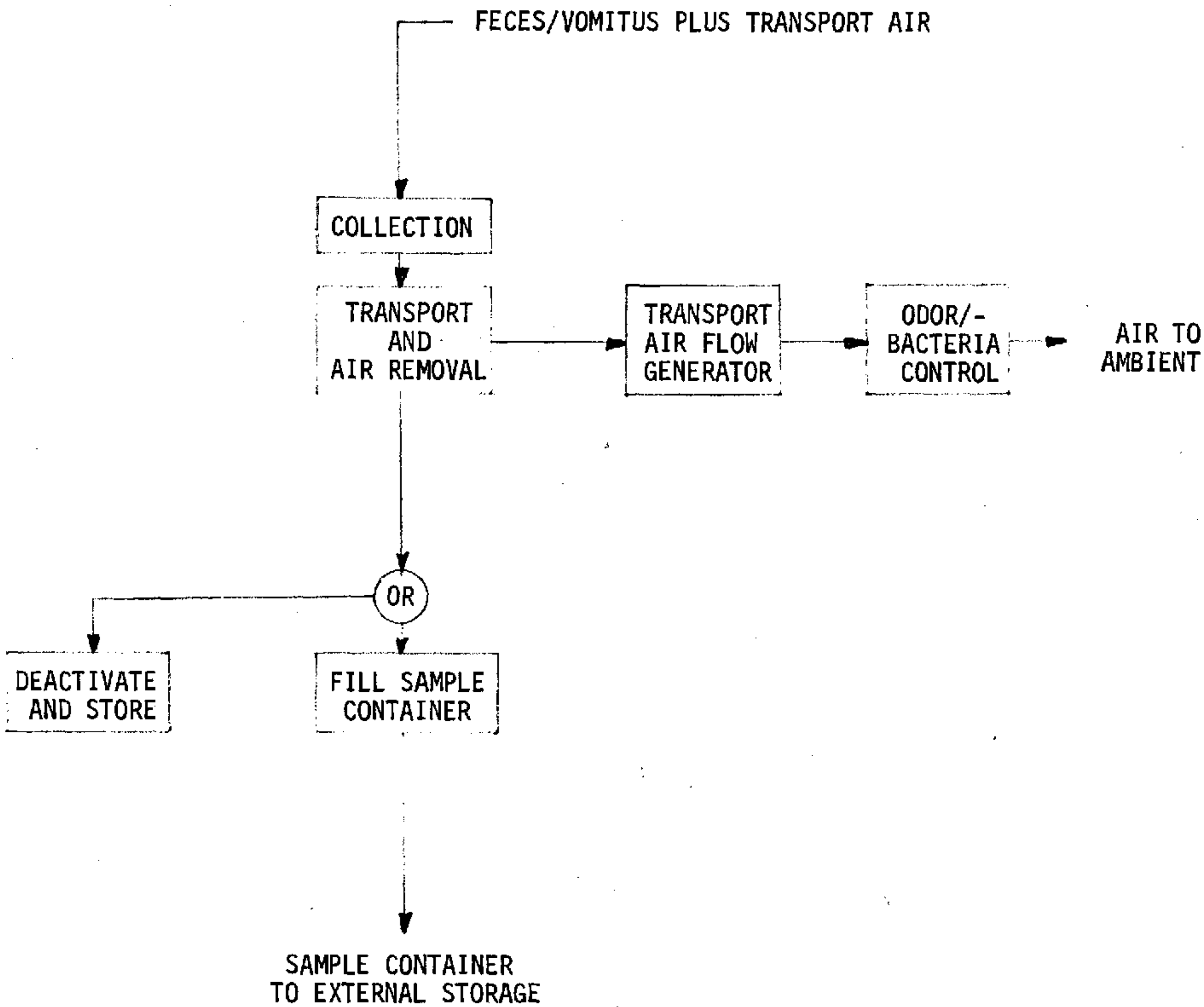


FIGURE 3.1.1.1-1. FUNCTIONAL BLOCK DIAGRAM, SOLIDS SUBSYSTEM OPERATING MODEL

3.1.1.1.4.6 Data Output

The Operating Model shall correlate the corresponding sample container number, user ID and mission time and record this information on an external recorder.

3.1.1.1.4.7 Maintenance

The Operating Model shall be designed to be easily maintainable including replacement of components.

3.1.1.1.4.8 Microorganism Control

The Operating Model shall be designed for automatic microorganism control of stored feces and vomitus. Air drying using ambient atmosphere shall be used as the control mechanism.

3.1.1.2 Secondary Performance Requirements

The Solids Subsystem Operating Model shall conform to the block diagram of Figure 3.1.1.2-1 and operating sequence of Figure 3.1.1.2-2. The Operating sequence for vomitus shall be similar to that of 3.1.1.2-2.

3.1.1.2.1 Configuration

The Solids Subsystem Operating Model shall be configured to fit within an envelope 18 inches high, 24 inches wide and 24 inches deep.

3.1.1.2.2 Weight

The Operating Model shall not be weight constrained.

3.1.1.2.3 Component Description

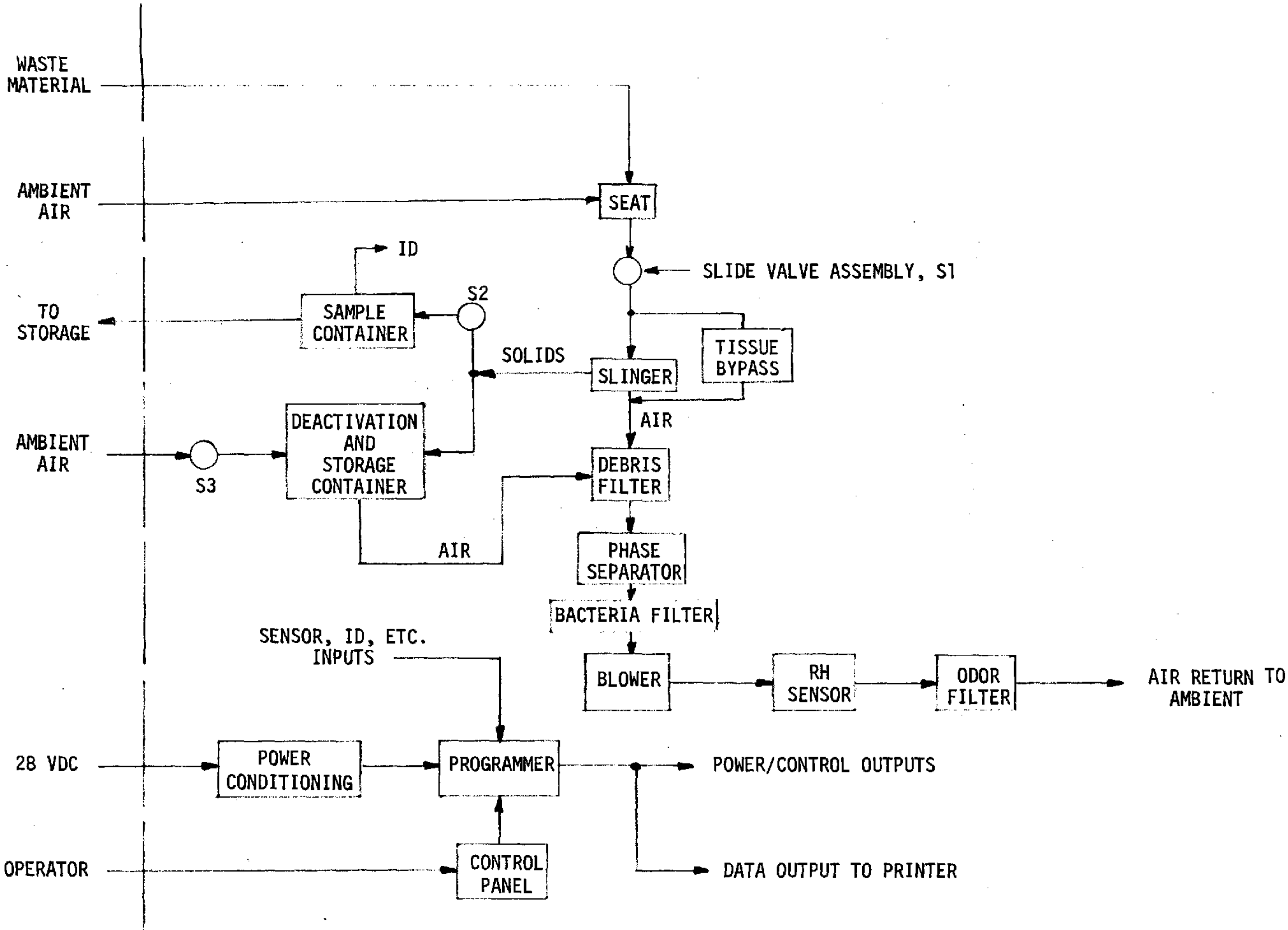


FIGURE 3.1.1.2-1. SOLIDS SUBSYSTEM BLOCK DIAGRAM

INITIATE COLLECTION, SAMPLING SEQUENCE
(POWER ON; POWER CONDITIONING, PROGRAMMER ACTIVATED)

- INSTALL SAMPLE CONTAINER (OPTIONAL)
- SET SUBJECT ID SELECTOR SWITCH
- OPEN INLET VALVE TO SAMPLE CONTAINER (OPTIONAL)
- ACTUATE FECES START SWITCH
- OPEN SLIDE VALVE: BLOWER AND SLINGER ASSEMBLY MOTORS* AND SENSOR ELECTRONICS ACTIVATED
- USER SEATED
  - USER DEFECATES
  - SAMPLE COLLECTED (OR DISTRIBUTED FOR AIR DRYING)
  - ACTUATE TISSUE BYPASS SWITCH
  - USER ID, TIME, SAMPLE CONTAINER DATA TO PRINTER
  - USER WIPES
  - CLOSE SLIDE VALVE
  - REMOVE SAMPLE CONTAINER
    - AIR DRYING (DEACTIVATION)
    - RH SENSOR SIGNAL (LOW RH); BLOWER AND SLINGER ASSEMBLY MOTORS OFF
      - TIME DELAY (1 HOUR)
        - AIR DRYING; BLOWER AND SLINGER ASSEMBLY MOTORS ON
        - RH SENSOR OR ELAPSED TIME SIGNAL; BLOWER AND SLINGER ASSEMBLY MOTORS OFF
        - CONTINUE ONE HOUR OFF, ON AS REQUIRED AIR DRY CYCLES
    - READY FOR NEXT USER

*DEPENDING ON DRYING CYCLE ACTIVITY, BLOWER AND SLINGER ASSEMBLY MOTORS MAY ALREADY BE OPERATING

FIGURE 3.1.1.2-2. OPERATING SEQUENCE

3.1.1.2.3.1 Seat Assembly

The seat assembly serves to align the user in a near central position with the axis of the slide valve assembly. Specific design requirements are as follows:

a. The seat opening shall be circular and a minimum 3.5 inches in diameter.

b. The seat surface shall be configured to achieve a comfortable load distribution, buttock cheek spreading and user confidence in positional alignment. Body "weight" shall be supported on the ischial tuberosities.

c. The seat surface shall be located a nominal 16 inches above the floor level.

d. The seat design shall be such as to permit simultaneous use of the Urine Subsystem Urinal Assembly.

e. The Seat Assembly shall provide for a relatively high velocity circumferential flow of ambient air over the user's anal area. The purpose of this airflow (generated by the blower, Section 3.1.1.3.2.7) is to both assist in disengagement and provide transport of the feces.

3.1.1.2.3.2 Slide Valve Assembly

The Slide Valve Assembly acts as a controllable interface between the seat assembly and the remainder of the subsystem elements. Specific design requirements are as follows:

a. The Slide Valve Assembly shall interface with and functionally interrupt the feces transport zone between the seat and tissue bypass.

b. The Slide Valve Assembly shall be manually operable.

c. The Slide Valve Assembly shall include a position switch so that initial valve movement will activate subsystem operation sequences.

d. Odors and/or microorganisms shall not be capable of migrating to ambient via the Slide Valve Assembly.

e. The slide valve shall incorporate an electrically operated interlock to inhibit opening unless activated.

3.1.1.2.3.3 Tissue Bypass

The function of the Tissue Bypass assembly is to direct wiping tissue into the storage container without contact with the slinger assembly. Specific design requirements are as follows:

a. Operation shall be automatic.

b. The Tissue Bypass shall positively interrupt the transport of wiping tissue into the slinger.

c. A position limit switch shall be provided for control purposes.

3.1.1.2.3.4 Slinger Assembly

The Slinger Assembly performs a number of closely related functions. The Slinger Assembly distributes the incoming fecal material in a thin layer about the inner periphery of the storage container to promote rapid air drying. The assembly also provides a debris and phase separation capability to prevent particles and/or liquids from entering the bacteria filter. Special design requirements are as follows:

a. The slinger shall be designed with 24 blades evenly spaced on a 5.0 inch diameter circle.

b. The slinger blades shall be shaped to minimize fecal solids build-up.

c. The slinger shall operate at a nominal 2000 rpm (no load).

d. All singer elements potentially exposed to fecal or vomitus material shall be teflon coated (to minimize retention).

e. The direction of rotation and orientation of slinger blades shall be compatible with operation of the Sampling Assembly (Section 3.1.1.2.3.4).

3.1.1.2.3.5 Sampling Assembly

The function of the Sampling Assembly is to automatically collect if desired, each fecal or vomitus discharge for later analysis. The assembly consists of a sample container per se, a drive motor and an isolating inlet valve for interfacing with the storage container (Section 3.1.1.2.3.5). Specific design requirements are as follows:

a. Each sample container shall consist of a flexible stainless steel sampling element contained within a semi-rigid metal/plastic enclosure. The sampling element shall be coated (on one side) with an open pore foam or equal to assist in containing normal or diarrhetic feces and/or vomitus.

b. Each sample container shall be serially numbered (alphanumeric and BCD format). The identification tab shall be compatible with an optical type read-out.

c. The sample container shall be designed for sterilization prior to use.

d. The sample container shall be capable of normal handling without leakage.

e. The sampling container shall be sized to collect a maximum of a single use discharge.

f. The sample container shall interface with the storage container via an inlet valve. This valve shall only be operable if a sample container is in place.

g. If sample containter is installed and inlet valve is open, the container sampling element shall be, on command, automatically driven into the storage chamber and guided to encircle the slinger blades. At the end of the use cycle, the sampling element is automatically retracted into the sample container by the drive motor.

h. Limit switches (or equal) shall be provided to control the drive motor.

3.1.1.2.3.6 Storage Container

The function of the Storage Container is to provide aseptic storage of waste inputs (when sampling is not desired). The storage container also serves as a structural support and/or to contain other susbystem elements. Specific design requirements are as follows:

a. The storage container shall be generally circular in shape and be sized for 168 man-days of use (6 men for 28 days).

b. The storage container shall accommodate used wiping tissue as well as feces and vomitus.

c. To position the liquid portion of diarrhetic or vomitus discharges during drying, an open pore foam type element shall be located within the storage container.

3.1.1.2.3.7 Bacteria Filter

The function of the bacteria filter is to trap airborne microorganisms (down to virus size) prior to the return of transport air or drying air to ambient. Specific design requirements are as follows:

a. The bacteria filter medium shall be capable of removing 98% of 0.04 micro size particles and 100% of size 0.6 micron (or larger) particles.

b. The pressure drop through the filter at 20 CFM (STP) shall be less than 1.0 inches of water.

c. The filter shall be sized for 168 man-days of operation.

3.1.1.2.3.8 Blower

The blower assembly provides transport air during a use cycle and drying air during drying cycles. Specific design requirements are as follows:

a. The blower shall operate at two speeds (to minimize power input during drying).

b. A transport air flow of 20 CFM (STP) shall be provided during high speed operation.

c. A drying air flow of 10 CFM (STP) shall be provided during low speed operation.

3.1.1.2.3.9 Relative Humidity Sensor

The function of the RF sensor is to determine air drying when the relative humidity of the exit air drops below a set value. Specific design requirements as follows:

a. The RF sensor shall terminate each air dry cycle when the RF of the exit air drops below 70%.

3.1.1.2.3.10 Odor Filter

The function of the oror filter is to adsorb noxious/toxic odors from the transport or drying air prior to return to ambient. A secondary function is to act as a noise muffler for the blower. Specific design requirements are as follows:

a. The odor adsorbing media shall be activated charcoal or equal.

b. The filter shall be sized for 168 man-days of operation.

c. A check valve shall be incorporated to minimize exposure to ambient during non-operating periods.

3.1.1.2.3.11 Programmer Assembly

The Programmer assembly shall provide the necessary functions for automatic operation as well as the circuitry necessary for proper presentation of data to the external recorder (printer). Specific design requirements shall be as follows:

a. The Programmer Assembly shall provide completely automatic operation after setting of control panel switches and actuating the Slide Valve Assembly.

b. Data to the external recorder printer shall be converted to BCD format.

c. All switch closures to the Programmer Assembly shall be buffered by digital switching to eliminate contact bounce effects.

d. Waste material microorganism deactivation via air drying shall be interruptable at user's option. Sampling shall also be a user option.

e. The Programmer shall be integrated into (and share functions with) the Prime Subsystem programmer.

3.1.1.2.3.12 Power Conditioning

The function of the power conditioning capability is to provide specific AC or DC voltages from a nominal 28 VDC input for operating the electronics or other subsystem elements. Specific requirements are as follows:

a. Power conditioning elements shall be integrated into (and shared with) the Prime Subsystem power conditioning components.

3.1.1.2.3.13 Container ID Sensors

The container ID sensors are used to read the container number. The container number shall be a three digit decimal number in BCD format; therefore, twelve (12) individual sensors are required to read the number. Specific design requirements for each sensor shall be as follows:

a. Diode excitation shall be 10 $^{+5}_{-2}$ MA.

b. Phototransistor output shall be 300 μa minimum when the output is "on" and 1 μa maximum in the "off" state.

3.1.1.2.3.14 Control Panel

The control panel layout shall conform to Figure 3.1.1.2-3 and shall be integrated into the Prime Subsystem panel.

3.1.1.2.3.15 Structure Assembly

A structure assembly shall be provided for mounting and supporting the Operating Model components. Specific design requirements shall be as follows:

a. The structure assembly with other system equipments installed, shall conform to the overall envelope dimensions of 3.1.1.2.1.

b. Specific equipments shall be located to minimize potential EMI problems and length of plumbing runs consistent with normal maintenance requirements.

c. The structure assembly shall be designed to withstand normal laboratory use.

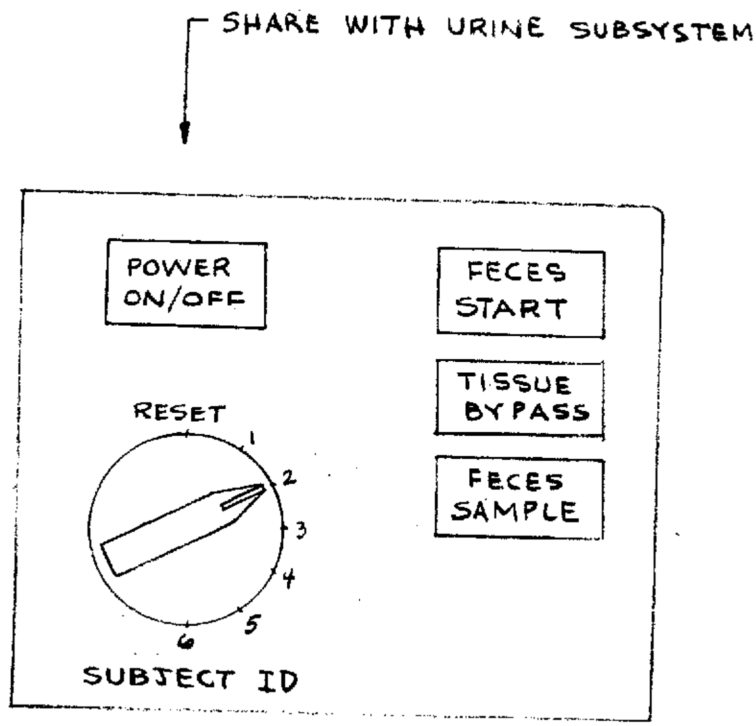
3.1.1.2.4 System Operation

The Solids Subsystem Operating Model shall conform to the following operational sequence (Reference Figures 3.1.1.2-1, 3.1.1.2-2, and 3.1.1.2-3).

3.1.1.2.4.1 Power ON

a. Power ON switch actuated by user.

b. Power ON indicator light activated.



NOTE: LOCATE ON URINE SUBSYSTEM CONTROL PANEL AREA.

FIGURE 3.1.1.2-3. CONTROL PANEL LAYOUT (NOT TO SCALE)

c. Subsystem control electronics activated (mission time starts when power ON initiated).

3.1.1.2.4.2 <u>Sample Container Installation</u>

a. Install sample container (optional).

3.1.1.2.4.3 <u>Collection, Sampling Cycle Initiation</u>

a. User sets the SUBJECT ID selector switch to the appropriate location via the RESET position. This action provides sample container and user data correlation. The cycle cannot be initiated until the sequence of return to RESET and then to the appropriate ID number has been accomplished.

b. User moves sample container inlet valve S2 to OPEN position.

   NOTE: This optional action cannot occur if sample container not installed.

c. User actuates FECES START switch.

d. FECES START switch indicator light activated. If ID selection not via RESET position, indicator light goes to flashing condition and subsystem operation inhibited via interlock with slide valve S1. Light OFF when ID selected as in 3.1.1.2.4.3(a).

e. User actuates Slide Valve S1 to OPEN position.

f. Initiation of valve S1 action closes slide valve S1 position switch.

g. Closing of valve S1 position switch activates blower (high airflow range) and slinger assembly. And if sample container inlet valve S2 open (see (b) above), actuates motor to drive container sampling element into place inside of the storage container (as controlled by sampling element position sensor). If inlet valve S2 closed, motor drive not actuated (even though sample container in place). TISSUE BYPASS switch indicator light activated to flashing condition.

h. User seated.

i. User defecates.

j. User activates TISSUE BYPASS switch.

k. TISSUE BYPASS switch indicator light OFF when assembly in bypass position. User ID, time and, if used, Sample Container number data transferred to recorder printers.

l. User wipes.

m. User moves Slide Valve S1 to closed position.

n. Slide Valve S1 closure changes blower to low airflow range and actuates motor drives to return sampling element to sample container (if used) and returns tissue bypass assembly to the flow through position.

o. Return of sampling element to initial position activates SAMPLE indicator light to flashing condition.

p. User closes sample container inlet valve S2, SAMPLE indicator light deactivated. NOTE: Closing of the inlet valve S2 cannot occur until sampling element returned to sample container.

q. User removes used sample container to storage.

r. User installs new sample container (optional).

s. System ready for next user.

3.1.1.2.4.4 <u>Solids Deactivation</u>

a. Simultaneously with 3.1.1.2.4.3(n) above, valve S3 energized OPEN. RF sensor energized and blower switched to low airflow operation. This action initiates air drying to deactivate the waste material microorganisms. During the first 5 minutes of air drying, the RF sensor signal output is inhibited.

b. After the 5-minute period, air drying continues until RF sensor signal indicates RF of exit air reduced to set level.

c. Receipt of RF sensor signal deactivates blower and slinger assembly motors and valve S3.

d. At approximately hourly increments, automatically reactivate drying sequence (a thru c above) for a minimum of 5 minutes or until cut-off by the RF sensor signal (slinger operating and blower on low airflow range).

e. Interruption of the Solids deactivation sequence by a user cycle automatically reverts the deactivation sequence to 3.1.1.2.4.4(a).

3.1.2 Operability

3.1.2.1 Reliability

Operating Model reliability shall be achieved by reliance on maintenance procedures rather than redundancy.

3.1.2.2 Maintainability

The Operating Model shall be designed to provide component accessibility, replaceability, and serviceability consistent with the intended use.

3.1.2.3 Useful Life

The Operating Model shall be designed for a minimum useful laboratory life, with maintenance, of 12 months.

3.1.2.4 Operating Environment

The Operating Model shall be designed to operate under conditions normally encountered in engineering or physiological test laboratories.

3.1.2.5 Human Engineering

Human Engineering factors shall be considered in the design and layout of the Operating Model.

3.1.2.6 Safety

3.1.2.6.1 User Safety

The Operating Model shall be designed to prevent hazardous conditions and inadvertent operation. Specifically,

a. Sharp edges, corners or equal shall be eliminated.
b. All electrical junction points shall be insulated or otherwise covered to prevent accidental contact.
c. All components shall be grounded to the structure with provisions on the structure for connecting to an external ground provided.

3.1.2.6.2 Equipment Safety

The Operating Model shall incorporate fail-safe features. Specifically, fault isolation protection shall be provided as required.

3.2 Interface Requirements

3.2.1 Urine Subsystem

The Solids Subsystem Operating Model shall be capable of operating with or independent of the Urine Subsystem Operating Model (except that electronic and control elements shall be shared as appropriate).

3.2.2 Electrical

The Operating Model shall operate on nominal 28 VDC power from an external source. Connection to the model shall be via a Bendix pygmy type connector.

3.2.3 Mechanical

The Operating Model shall be self-supporting (structurally).

3.2.4 Fluid

The Operating Model shall use ambient air for the drying cycle.

3.2.5 Recorder Printer

The Operating Model shall be capable of interfacing with an external recorder printer. The function of the printer is to provide a permanent record of the time of each feces or vomitus input, correlated with the subject ID and sample container number. Specific requirements are as follows:

a. The printer shall have six (6) columns.

b. The input to each column will be four (4) TTL compatible lines in BCD format.

c. The print time shall be less than 500 MS.

d. The printer shall operate on 115 VAC at 60 Hz power.

e. Tape printout format and code shall conform to Figure 3.1.2-1 and 3.1.2-2.

3.2.6 User

The Operating Model shall be designed for use by male and female subjects.

4.0 TEST REQUIREMENTS

DIRECTION OF PAPER TRAVEL

```
XXXXXX
XXXXXX
XXXXXX
XXXXXX
242127   - USER 2 @ 421.2 HOURS: CONTAINER NO. 18
000018
542367   - USER 5 @ 423.6 HOURS; CONTAINER NO. 19
000019
XXXXXX
XXXXXX
XXXXXX
342977   - USER 3 @ 429.7 HOURS
000000
XXXXXX
XXXXXX
```

FIGURE 3.1.2-1. TYPICAL PRINTOUT

FOR EACH USE, TWO LINES:

USER ID (NUMERALS 1 THRU 6)

MISSION TIME, HOURS TO NEAREST TENTH

FECES COLLECTION ID (USE NUMERAL 7)

LINE 1 X X X X X X

SPARES

CONTAINER NUMBER (1 TO 999)

LINE 2 X X X X X X

FIGURE 3.1.2-2. TAPE PRINTOUT CODE

4.1 Quality Assurance

A minimal quality assurance program shall be performed consistent with the design status of the Solids Subsystem Operating Model. The intent of this effort shall be to provide valid background information for subsequent program phases. Specific requirements are as follows:

a. Perform a preliminary FMEA, with safety emphasized.
b. Maintain configuration control records, i.e., provide a good record of what was fabricated and tested.
c. Perform laboratory tests to compare actual performance with specification requirements.
d. Fabricate in accordance with good commercial practice.

4.2 Verification

The performance of the Solids Subsystem Operating Model shall be determined with specific development tests as follows:

a. Verify subsystem operating conditions/cycles.
b. Determine mass of retained sample.
c. Determine transport air flow rate.

5.0 DATA LIST

Documentation pertaining to the Solids Subsystem Operating Model shall be provided as follows:

a. Specification Requirements
b. Top Assembly
c. Manufacturing Drawings for Fabricated Components
d. Vendor Data Sheets for Purchased Components
e. Wiring Diagrams
f. Verification Test Report (may be combined with [g])
g. Final Program Report.

7.2 List of Drawings

DRAWING LIST

Mechanical

SK56198-800	ABS System Inst'l
SK56198-801	Solids S/S Assy
SK56198-802	Container
SK56198-803	Valve Assy, Sample Inlet
SK56198-804	Inlet Assy
SK56198-805	Lock, Slide Valve
SK56198-806	Support, Slide Valve
SK56198-808	Tissue Bypass
SK56198-809	Slide Valve
SK56198-810	Inlet Adapter
SK56198-811	Slinger
SK56198-814	Drive Assy, Bypass
SK56198-816	Slide Valve, Solids Sample
SK56198-817	Support, Tissue Bypass
SK56198-818	Guide Plates
*SK56198-819	Collection Strip - Samples
SK56198-820	Housing, Solids Sample
SK56198-825	Solids S/S Container Assy

Electrical

ER47D220984	Solids S/S Schematic

7.3 Operating Instructions

The Solids Subsystem Operating Model represents an automated approach to solid biowaste collection and storage or sampling. Subsystem operation requires the following user actions prior to and during use.

7.3.1 Set-Up

7.3.1.1 Installation

a. Connect to 28 VDC supply (including ground lead) via Urine Subsystem Operating Model.

7.3.1.2 Check-Out

a. Install sample container.

b. Cycle the subsystem thru the normal operation sequences (See 7.3.2 Below).

7.3.2 Normal Operation

7.3.2.1 Power ON

a. Actuate power ON switch (on Urine Subsystem Operating Model).
Note: Mission time starts at this action.

7.3.2.2 Sample Container Installation

a. Install sample container (optional).

7.3.2.3 Collection/Sampling

a. Set SUBJECT ID selector switch via the reset position.

b. Move sample container inlet valve to open position (optional). This optional action cannot occur if a sample container is not installed.

c. Actuate START switch (See Table 7.3-1).

d. Open slide valve. This action cannot be accomplished if power not ON and subject ID not selected.

e. Be seated and defecate.

f. When defecation complete, actuate TISSUE BYPASS switch (See Table 7.3-1).

g. Wipe and deposit tissue into subsystem via seat opening.

h. Close slide valve.

i. Close sample container (if used) inlet valve (See Table 7.3-1).

j. Remove sample container (if used).

k. Subsystem ready for next user.

TABLE 7.3-1. DISPLAY INDICATION

INDICATOR LIGHT	LIGHT	SUBSYSTEM CONDITION
1. Power ON	Solid	Power On, Normal
2. START	Solid	Normal Operation
	Flashing	Subject ID Not Selected Via Reset Position.
3. TISSUE BYPASS	Flashing	Normal (Operator alert; Light Off When Switch Actuated).
4. SAMPLE	Flashing	Normal (Operator Alert; Light Off When Sample Container Inlet Valve Closed).

7.4 Component Data Sheets

Component data sheets as available for major purchased items are included in this section in the following order.

1. Planetary Gearmotors, Globe Industries
2. Purafil
3. Blower, IMC Magnetics Corp.
4. RH Transducer, Hygrodynamics, Inc.

torque:
Up to 300 oz. in. maximum continuous torque.

voltage:
6 to 50 v.d.c.

size:
¾" diameter.

weight:
4 to 9 oz., depending on ratio.

gears:
Planetary gearing system. All gears are precision manufactured and heat-treated for consistently reliable performance and life.

backlash:
Varies with ratio but average will have less than 3°.

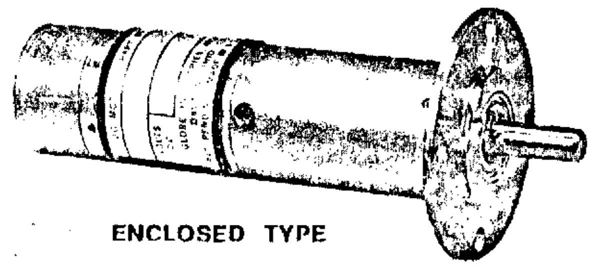
bearings:
Output shaft is supported by two double-shielded, life-lubricated ball bearings.

electrical connection:
Solder terminals are provided on open type. 8" leads on enclosed type.

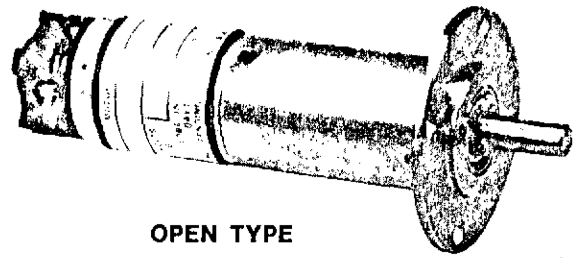
mounting:
Unit is mounted by pilot and four holes in flange.

GLOBE INDUSTRIES DIVISION OF TRW INC.
2275 Stanley Avenue · Dayton, Ohio 45404
Telephone: 513 222-3741 · TWX: 810 459-1642

TYPE SD



ENCLOSED TYPE



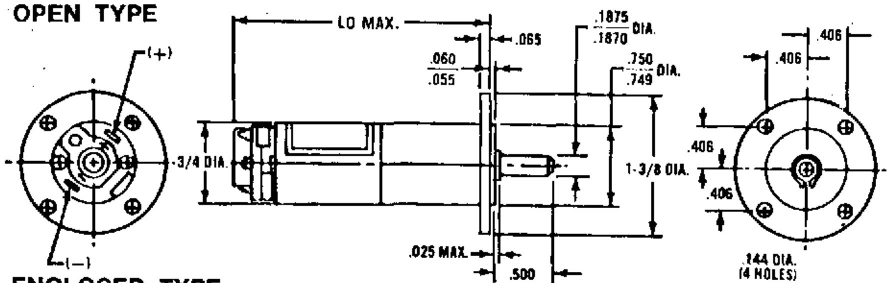
OPEN TYPE

This small size, light weight gearmotor is comprised of Globe's ¾" Type SD motor, Bulletin A-1200N coupled with a precision planetary gear train. The combination provides smooth, dependable performance and maximum output torque in the smallest possible space. It is designed to provide a military quality gearmotor of exceptionally compact size.

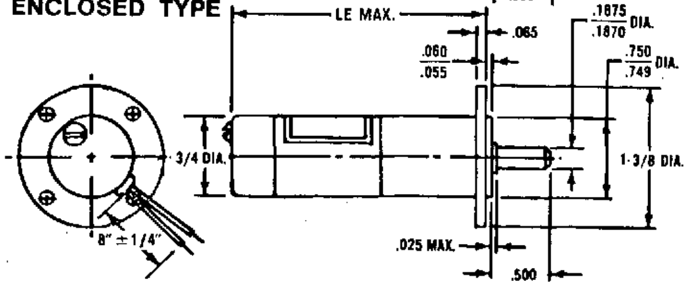
Nineteen different reduction ratios, ranging from 14.58:1 to 36,873:1, are available. These subminiature Globe gearmotors are designed to meet the applicable environmental specifications of MIL-M-8609.

DIMENSIONS

OPEN TYPE



ENCLOSED TYPE



Note:
Be sure to check Globe for latest data prior to preparing spec control prints.

STANDARD PART NUMBERS AND DATA

SPEED REDUCTION RATIO	MAXIMUM CONTINUOUS TORQUE (1) (oz. in.)	TORQUE (2) MULTIPLICATION RATIO	LO MAX.	LE MAX.	STANDARD PART NUMBERS* open type	enclosed type
3.82	1.0	3.1	2⅜″	2 13/32″	168A247	168A249
5.77	1.5	4.6			168A248	168A250
14.58	3.0	9.3	2 39/64″	2 41/64″	168A204	168A223
22.03	4.5	14			168A205	168A224
33.28	7.0	21			168A206	168A225
55.66	10	28	2 25/32″	2 13/16″	168A207	168A226
84.11	14	43			168A208	168A227
127.1	21	65			168A209	168A228
192	30	93			168A210	168A229
321	45	130	2 61/64″	2 63/64″	168A211	168A230
485	70	200			168A212	168A231
733	100	300			168A213	168A232
1108	150	450			168A214	168A233
1853	200	600	3⅛″	2 5/32″	168A215	168A234
2799	300	900			168A216	168A235
4230	300	1400			168A217	168A236
6391	300	2100			168A218	168A237
10689	300	2800	3 19/64″	3 21/64″	168A219	168A238
16150	300	4200			168A220	168A239
24403	300	6400			168A221	168A240
36873	300	9700			168A222	168A241

(1) This is the maximum continuous output torque rating of a given geartrain. Actual output depends upon the armature winding selected. See Bulletin A-1200N, Type SD motors, for rated torque of various armatures.

(2) Maximum continuous output torque of the gearmotor is the product of the multiplication ratio times the rated torque of the motor as given in Bulletin A-1200N. This value must not exceed the maximum continuous torque given in the second column, above. Minimum efficiency of the geartrain is the product of the multiplication ratio divided by the speed ratio times 100%.

Orange blocks indicate units not normally stocked by Globe distributors.

BASIC MOTOR DATA

VOLTAGE (v.d.c.)	SPEED no load (rpm)	TORQUE max. rated (oz. in.)	TORQUE nominal stall (oz. in.)	CURRENT max. no load (amps)	CURRENT max. rated load ** (amps)	CURRENT nominal stall (amps)	ARMATURE DASH NO.*
6	14,500-17,500	0.20	1.50	.460	0.78	3.6	-17
6	12,000-14,000	0.28	1.20	.380	0.78	2.2	-16
6	9,000-10,500	0.32	0.90	.270	0.60	1.4	-15
12	13,000-15,500	0.22	1.60	.220	.38	1.50	-14
12	9,500-11,000	0.37	0.80	.155	.37	0.93	-13
12	8,500-10,000	0.25	0.60	.135	.26	0.70	-12
27	15,500-18,500	0.17	1.80	.110	.17	1.15	-1
27	13,000-16,000	0.22	1.50	.100	.17	0.85	-2
27	10,000-12,500	0.31	1.20	.080	.17	0.48	-3
27	9,000-10,500	0.31	0.90	.065	.14	0.30	-4
27	7,000- 8,500	0.24	0.80	.055	.08	0.21	-5
50	13,000-15,500	0.26	0.90	.050	.10	0.22	-7
50	11,500-13,500	0.31	1.10	.045	.10	0.26	-6
50	11,000-13,000	0.26	0.75	.040	.08	0.18	-8
50	8,000- 9,500	0.18	0.50	.032	.05	0.08	-9
50	7,000- 8,300	0.15	0.45	.028	.04	0.07	-10
50	5,500- 6,500	0.11	0.35	.023	.03	0.05	-11

**GEARMOTOR NO LOAD CURRENT

WHEN YOU ORDER

***Part Number.** Units shown above are standard and may be ordered by part number. Complete part number consists of the basic part number plus a dash number to designate armature voltage and speed. Consult Globe for other voltages and variations for special applications.

For accessories and modifications, see introduction to this catalog section, page 7.

torque:
Up to 1250 oz. in. maximum continuous torque.

voltage:
4 to 75 v.d.c.

size:
1¼" diameter. Length depends on reduction ratio.

weight:
6 to 14 ounces depending on ratio.

gears:
Planetary gearing system. All gears are precision manufactured and heat treated for consistently reliable performance and long life.

backlash:
Varies with reduction but average unit will have less than 3°.

protection:
Gearmotor housing is cadmium plated to conform to QQ-P-416 Type 2 for protection against moisture, fungus and salt spray.

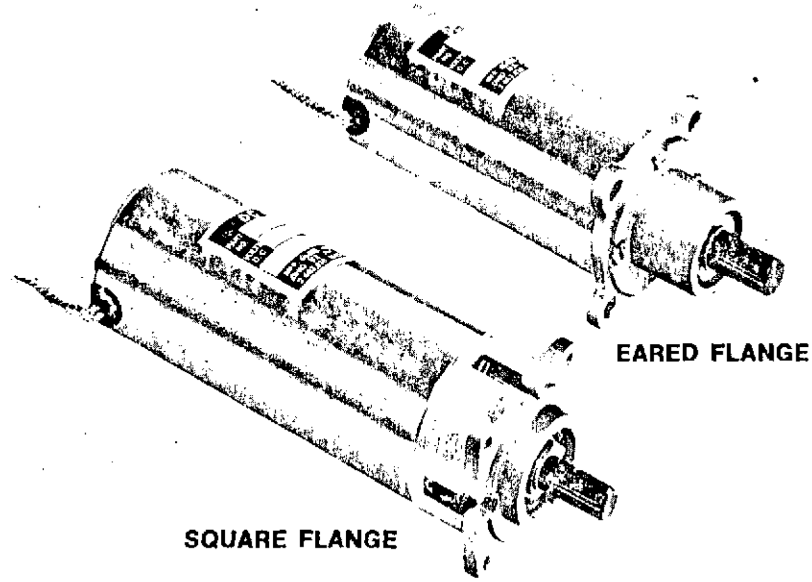
bearings:
Output shaft is supported by life-lubed ball bearings.

shaft:
Shaft is No. 416 precision ground stainless steel per QQ-S-763, heat treated and black oxide coated per MIL-C-13924A Class 1. Shaft and last gear carrier are of one-piece construction for maximum reliability.

electrical connection:
Two shielded cables #22 AWG per MIL-W-16878 (NAVY) Type "E."

mounting:
Standard flange—fourthrough holes.

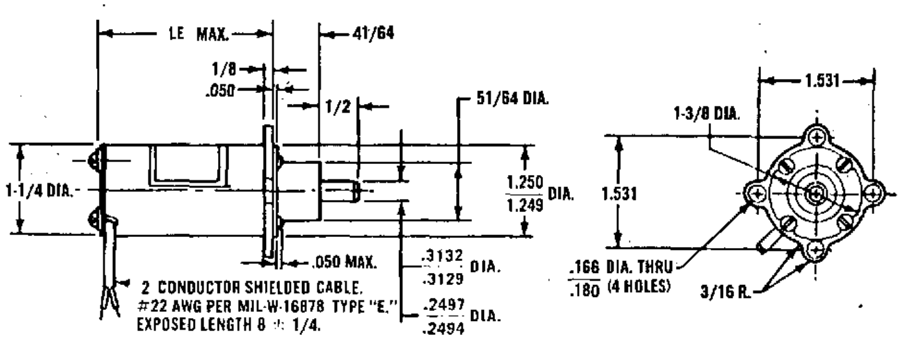
TYPE MM AND LL

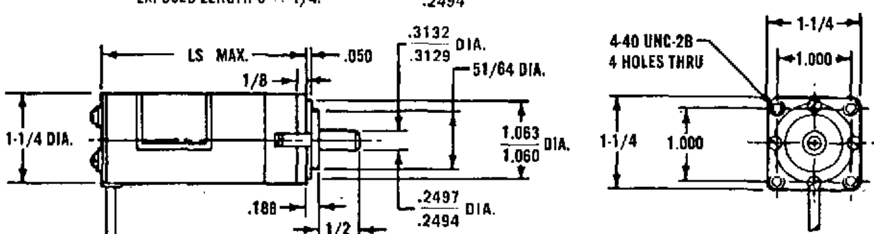


Globe's Type MM and LL planetary gearmotors provide torques to 1,000 oz. in. Gearmotors are 1¼" in diameter and are available with eared or square flanges as shown above. Over-all length ranges up to 5" depending upon speed reduction ratio. Eighteen different standard ratios, from 18.78:1 to 21,808:1, are available. These compact Globe gearmotors are designed to meet environmental portions of MIL-M-8609.

Please submit complete application details for a Globe engineering recommendation.

DIMENSIONS





CCW ROTATION VIEWED FROM SHAFT END WHEN RED LEAD IS POSITIVE (+) AND BLACK LEAD IS NEGATIVE (−).

Note:
Be sure to check Globe for latest data prior to preparing spec control prints.

GLOBE INDUSTRIES DIVISION OF TRW INC.
2275 Stanley Avenue • Dayton, Ohio 45404
Telephone: 513 222-3741 • TWX: 810 459-1642

STANDARD GEARMOTOR PART NUMBERS AND DATA

SPEED REDUCTION RATIO	MAXIMUM CONTINUOUS TORQUE (oz. in.)	TORQUE MULTIPLIER RATIO	TYPE MM GEARMOTOR PART NUMBERS* eared flange (5/16" shaft)	** eared flange (1/4" shaft)	square flange (5/16" shaft)	** square flange (1/4" shaft)	dim. LE	dim. LS	TYPE LL GEARMOTOR PART NUMBERS* eared flange (5/16" shaft)	** eared flange (1/4" shaft)	square flange (5/16" shaft)	** square flange (1/4" shaft)	dim. LE	dim. LS
4.33	5.4	3.2	5A533	5A2290	5A534	5A2310	2.437	2.891	5A497	5A2330	5A498	5A2350	2.781	3.234
5.29	6.8	4	5A535	5A2291	5A536	5A2311			5A499	5A2331	5A500	5A2351		
18.78	20	12	5A537	5A2292	5A538	5A2312			5A501	5A2332	5A502	5A2352		
27.94	29	17	5A539	5A2293	5A540	5A2313			5A503	5A2333	5A504	5A2353		
81.37	70	41	5A541	5A2294	5A542	5A2314	2.562	3.016	5A505	5A2334	5A506	5A2354	2.928	3.375
121.10	105	62	5A543	5A2295	5A544	5A2315			5A507	5A2335	5A508	5A2355		
147.70	128	75	5A545	5A2296	5A546	5A2316			5A509	5A2336	5A510	5A2356		
352.60	247	145	5A547	5A2297	5A548	5A2317	2.828	3.281	5A511	5A2337	5A512	5A2357	3.187	3.641
524.60	366	215	5A549	5A2298	5A550	5A2318			5A513	5A2338	5A514	5A2358		
639.90	445	262	5A551	5A2299	5A552	5A2319			5A515	5A2339	5A516	5A2359		
780.60	544	320	5A553	5A2300	5A554	5A2320			5A517	5A2340	5A518	5A2360		
1528.00	850	500	5A555	5A2301	5A556	5A2321	3.203	3.656	5A519	5A2341	5A520	5A2361	3.562	4.016
2273.00	1250	740	5A557	5A2302	5A558	5A2322			5A521	5A2342	5A522	5A2362		
3382.00	1250	1100	5A559	5A2303	5A560	5A2323			5A523	5A2343	5A524	5A2363		
4126.00	1250	1350	5A561	5A2304	5A562	5A2324			5A525	5A2344	5A526	5A2364		
6621.00	1250	1730	5A563	5A2305	5A564	5A2325	3.344	3.797	5A527	5A2345	5A528	5A2365	3.687	4.141
9851.00	1250	2580	5A565	5A2306	5A566	5A2326			5A529	5A2346	5A530	5A2366		
12016.00	1250	3150	5A567	5A2307	5A568	5A2327			5A531	5A2347	5A532	5A2367		
17879.00	1250	4700	5A569	5A2308	5A570	5A2328			5A533	5A2348	5A534	5A2368		
21808.00	1250	5700	5A571	5A2309	5A572	5A2329			5A535	5A2349	5A536	5A2369		

Orange blocks indicate units not normally stocked by Globe distributors.

BASIC MOTOR DATA

MM MOTORS

VOLTS	NO LOAD SPEED (rpm)	RATED TORQUE (oz. in.)	NOMINAL BREAKAWAY TORQUE (oz. in.)	GEARMOTOR NO LOAD CURRENT (amps)	MAX. CURRENT AT RATED TORQUE (amps)	NOMINAL STALL CURRENT (amps)	WINDING DASH NUMBER
4	16,000-19,000	.25	6.2	1.86	2.4	24.0	–23
6	18,900-22,500	.5	7.2	1.42	2.3	17.0	–14
6	15,600-18,600	.85	6.0	1.15	2.3	10.0	–6
6	12,000-14,000	.75	4.5	.96	2.0	9.0	–5
12	18,000-21,400	.50	6.8	.69	1.2	8.7	–24
12	14,500-17,000	.70	4.0	.60	1.2	6.0	–3
12	12,400-14,700	.75	4.7	.50	1.2	5.0	–21
12	11,000-13,000	1.0	4.0	.44	1.2	3.7	–4
24	19,200-22,800	.35	7.3	.39	.60	6.3	–7
24	16,000-19,000	.60	4.8	.31	.60	3.7	–1
24	11,500-14,000	1.0	4.0	.22	.60	2.2	–2
24	10,700-12,700	1.0	4.1	.21	.60	1.8	–8
24	9,600-11,400	1.0	3.6	.19	.50	1.3	–22
24	8,000-10,000	1.0	3.0	.16	.45	1.0	–10
24	6,000-7,000	.8	2.4	.11	.30	.6	–11
50	14,300-17,000	.7	5.4	.14	.30	1.5	–25
50	9,500-11,500	1.0	3.5	.09	.30	.7	–16
50	8,000-10,000	1.0	2.8	.08	.20	.5	–12
50	6,700-8,000	.8	2.5	.06	.16	.4	–15
50	4,600-5,500	.8	1.7	.05	.12	.2	–13

LL MOTORS

VOLTS	NO LOAD SPEED (rpm)	RATED TORQUE (oz. in.)	NOMINAL BREAKAWAY TORQUE (oz. in.)	GEARMOTOR NO LOAD CURRENT (amps)	MAX. CURRENT AT RATED TORQUE (amps)	NOMINAL STALL CURRENT (amps)	WINDING DASH NUMBER
6	15,600-18,500	1.0	12.0	1.53	2.7	16.0	–23
6	12,500-14,500	1.3	9.5	1.20	2.4	15.0	–14
6	10,000-12,200	1.6	8.0	1.05	2.6	13.0	–6
6	7,600-9,400	1.6	6.0	.78	2.0	8.0	–5
12	11,500-14,000	1.1	8.0	.63	1.7	7.0	–24
12	9,000-11,000	1.7	5.2	.47	1.2	4.5	–3
24	16,000-19,000	.75	8.8	.45	1.0	7.5	–21
24	14,400-17,000	.85	7.8	.38	.85	6.0	–4
24	12,000-14,500	1.0	7.5	.33	.80	5.2	–7
24	10,400-12,300	1.1	6.2	.28	.75	3.3	–1
24	7,400-8,900	1.6	5.5	.20	.70	2.1	–2
24	6,900-8,200	1.8	3.8	.19	.65	1.6	–8
24	6,200-7,400	1.8	3.4	.17	.60	1.3	–22
24	5,200-6,200	1.2	2.8	.15	.45	1.2	–10
50	7,600-9,400	1.5	7.5	.10	.25	1.1	–11
75	14,000-17,000	1.0	10.0	.12	.29	1.9	–25
75	9,000-11,000	1.7	8.0	.08	.29	1.0	–16
75	8,000-10,000	1.8	6.0	.07	.26	.6	–12
75	6,500-8,000	1.2	5.5	.06	.20	.4	–15
75	4,500-5,300	1.0	2.5	.05	.10	.2	–13

WHEN YOU ORDER

***Part Number.** Each of the basic motor windings (bottom chart) can be used with any of the gear ratios listed in the top chart. To order, state the gearmotor part number plus a motor winding dash number. EXAMPLE: 5A537-1 is an 18.78:1 MM gearmotor with a —1 armature winding, 24 volts, 17,500 rpm, 0.5 oz. in. torque, etc.

**1/4" dia. shaft units limited to 600 oz. maximum continuous duty torque.

To Find Output Torque: maximum continuous output torque of the gearmotor is the product of motor torque times the torque multiplier ratio. This figure is limited by the maximum continuous torque listed in the chart above.

For accessories and modifications, see introduction to this catalog section, page 7.

rating:
To 550 lb. in. continuous duty.
To 1,100 lb. in. intermittent duty.

voltage:
6 to 115 v.d.c.

weight:
Varies with motor and gear reduction ratio.

gears:
Precision manufactured and heat treated for reliable performance and long life.

backlash:
Varies with ratio, but maximum backlash is 3°.

protection:
Motor housing is black anodized per MIL-A-8625 Type II. Unit is designed for protection against moisture, fungus, shock, and salt spray. Geartrain housing is protected by paint and irridite. Normal operating temperature range is −55°C to +85°C.

bearings:
Anti-friction ball or roller bearings are used at every bearing location including all planet gears.

lubrication:
Life-lubricated bearings and geartrains are standard. Consult Globe about special lubricants for temperature extremes.

shaft:
Carbon steel shaft per QQ-S-624 with 18 tooth spline serrations per ASA B5.15-1960 heat treated to Rc 45-48 (1⅞" flange) and Rc 29-33 (3" flange).

electrical connection:
Double conductor shielded cable (#22 AWG) per MIL-W-16878 Type "E".

mounting:
Four holes and pilot are standard.

GLOBE INDUSTRIES DIVISION OF TRW INC.
2275 Stanley Avenue · Dayton, Ohio 45404
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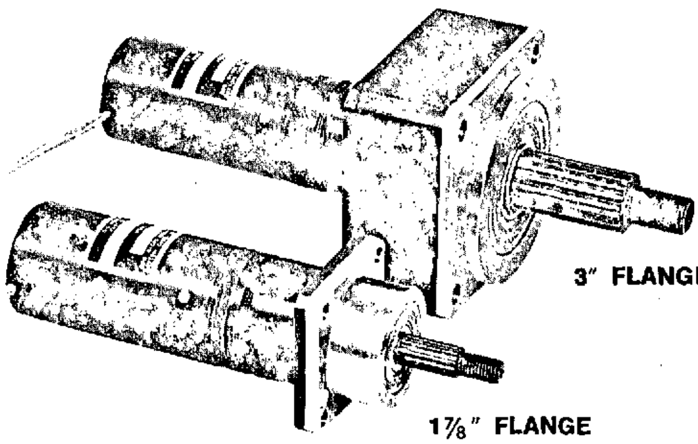
TYPE BD & BL



3" FLANGE

1⅞" FLANGE

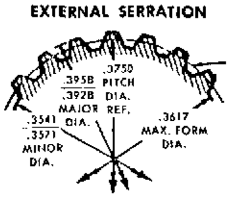
Globe's 1½" diameter planetary geartrains provide high torque outputs in a small package. Coupled to the Globe Type BD or BL motor, they are ideal for business machinery, machine tools, aircraft, and missile applications.

Anti-friction bearings in each planetary gear stage result in efficiencies of over 90% per stage. Two geartrain sizes, 1⅞" Flange and 3" Flange, provide continuous duty output torques to 100 lb. in. and 550 lb. in. respectively.

These geartrains can also be integrally coupled with other Globe units, including a.c. and universal motors. Consult Globe for an engineering recommendation to meet your requirements.

SHAFT DATA: 1⅞" FLANGE

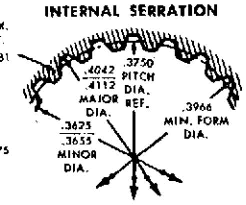
EXTERNAL SERRATION



EXTERNAL MAX. EFF.	EXTERNAL MIN. EFF.		INTERNAL MIN. EFF.	INTERNAL MAX. EFF.
.0369	.0357	CIRCULAR TOOTH THICKNESS	.0369	.0381
		NUMBER OF TEETH	18	
		PITCH	48/96	
		PRESSURE ANGLE	45°	
		LENGTH OF ENGAGEMENT	¾ REF.	
.4397		MIN. MEAS. OVER TWO .040 PINS		
		MAX. MEAS. BETWEEN TWO .040 PINS	.3175	

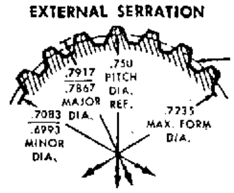
Customer's Part: For prototype use, Globe will broach holes in parts with $\frac{.3575}{.3585}$ I.D. broach hole starting diameter.

INTERNAL SERRATION



SHAFT DATA: 3" FLANGE

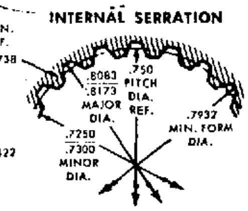
EXTERNAL SERRATION



EXTERNAL MAX. EFF.	EXTERNAL MIN. EFF.		INTERNAL MAX. EFF.	INTERNAL MIN. EFF.
.0738	.0726	CIRCULAR TOOTH THICKNESS	.0750	.0738
		NUMBER OF TEETH	18	
		PITCH	24/48	
		PRESSURE ANGLE	45°	
		LENGTH OF ENGAGEMENT	1½ REF.	
.8818		MIN. MEAS. OVER TWO .080 PINS		
		MAX. MEAS. BETWEEN TWO .080 PINS	.6322	

Customer's Part: For prototype use, Globe will broach holes in parts with $\frac{.7195}{.7205}$ I.D. broach hole starting diameter.

INTERNAL SERRATION



Note:
Be sure to check Globe for latest data prior to preparing spec control prints.

BASIC MOTOR PERFORMANCE AND DATA

TYPE BD

VOLTAGE (v.d.c.)	SPEED (rpm)	TORQUE max. rated (oz. in.)	TORQUE nom. stall (oz. in.)	CURRENT gear-motor max. no load (amps)	CURRENT max. rated load (amps)	CURRENT nom. stall (amps)	ARMATURE DASH NO.*
6	13,000-15,500	1.7	14	1.70	4.5	34.0	–2
6	10,000-12,000	2.3	13	1.40	4.6	24.0	–3
6	8,000- 9,500	3.2	12	1.10	4.6	17.0	–4
12	12,500-14,500	1.8	17	.85	2.3	19.0	–5
12	10,000-12,000	2.4	13	.70	2.3	12.5	–6
12	8,000- 9,500	3.2	12	.55	2.3	8.4	–7
27	14,000-16,500	1.6	19	.45	1.0	11.8	–8
27	11,000-13,000	2.0	18	.39	1.0	8.8	–9
27	9,000-10,500	2.8	15	.27	1.0	5.3	–10
27	7,000- 8,500	3.6	14	.23	1.0	3.5	–11
50	10,500-12,500	2.1	17	.18	.5	4.3	–12
50	8,000- 9,500	2.8	14	.145	.5	2.8	–13
50	6,500- 8,000	3.7	13	.11	.5	1.9	–14
50	5,000- 6,500	3.5	11	.09	.4	1.3	–15
115	13,000-15,500	1.6	17	.10	.3	2.1	–16
115	11,000-13,000	2.2	14	.08	.3	1.5	–17
115	9,000-10,500	2.8	12	.07	.3	1.1	–18
115	7,000- 8,500	3.6	11	.065	.3	.7	–19
115	6,000- 7,000	2.9	10	.05	.2	.5	–20
115	4,500- 5,500	2.7	9	.045	.2	.5	–21

TYPE BL

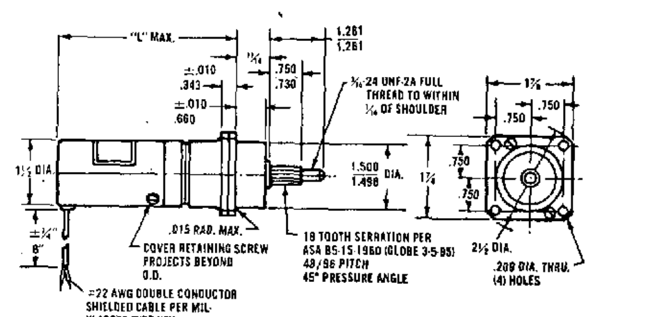
VOLTAGE (v.d.c.)	SPEED no load (rpm)	TORQUE max. rated (oz. in.)	TORQUE nom. stall (oz. in.)	CURRENT gear-motor max. no load (amps)	CURRENT max. rated load (amps)	CURRENT nom. stall (amps)	ARMATURE DASH NO.*
6	10,000-12,500	3.3	24	1.60	5.2	39.0	–1
6	8,500-10,500	4.0	20	1.30	5.2	28.0	–2
6	6,500- 8,000	5.0	17	1.00	5.1	21.0	–3
12	10,000-12,500	3.3	24	.77	2.6	24.0	–4
12	8,500-10,500	4.4	21	.61	2.7	15.5	–5
12	6,500- 8,000	5.0	18	.49	2.8	10.5	–6
27	11,500-14,000	2.9	28	.40	1.4	16.0	–7
27	8,500-10,500	3.7	27	.31	1.4	11.0	–8
27	7,000- 9,000	5.0	23	.25	1.4	7.0	–9
27	5,500- 7,000	6.0	21	.20	1.4	5.5	–10
50	8,500-10,500	3.8	29	.17	.72	6.5	–11
50	6,500- 8,000	5.0	25	.13	.74	4.5	–12
50	5,500- 7,000	6.5	21	.10	.73	3.2	–13
50	4,500- 5,500	7.5	19	.085	.66	2.0	–14
50	3,500- 4,500	6.0	18	.065	.43	1.4	–15
115	8,500-10,500	4.2	19	.075	.34	1.6	–16
115	7,000- 9,000	5.0	18	.065	.40	1.2	–17
115	5,500- 7,000	5.0	15	.050	.28	0.8	–18
115	4,500- 5,500	4.2	14	.040	.19	0.6	–19
115	4,000- 5,000	3.5	11	.035	.14	0.4	–20
115	3,000- 4,000	2.9	9.5	.030	.10	0.3	–21

Orange blocks indicate units not normally stocked by Globe distributors.

STANDARD PART NUMBERS AND GEARMOTOR DATA

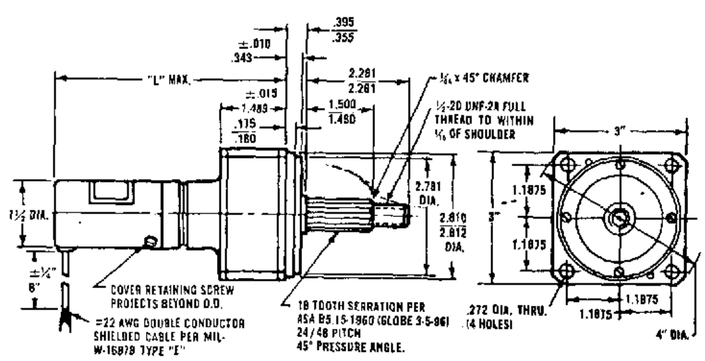
1⅞" FLANGE

SPEED REDUCTION RATIO	TORQUE MULTIPLIER	MAX. CONT. RATING (lb. in.)	TYPE BD "L" max.	TYPE BD standard part no.*	TYPE BL "L" max.	TYPE BL standard part no.*
3.81:1	3.5	1.1	3.34	102A152	3.72	102A170
5.54:1	5.1	1.6		102A153		102A171
14.5 :1	13	4.1	3.53	102A156	3.91	102A174
21.1 :1	19	6.0		102A157		102A175
30.7 :1	27	8.6		102A158		102A176
55.3 :1	47	14.6	4.09	102A160	4.47	102A178
80.4 :1	68	21.0		102A161		102A179
117.0 :1	99	31.0		102A162		102A180
170.0 :1	144	45.0		102A163		102A181
211.0 :1	171	53.0	4.28	102A189	4.66	102A199
306.0 :1	248	77.0		102A190		102A200
445.0 :1	360	100.0		102A191		102A201
647.0 :1	524	100.0		102A192		102A202
941.0 :1	762	100.0		102A193		102A203



3" FLANGE

SPEED REDUCTION RATIO	TORQUE MULTIPLIER	MAX. CONT. RATING (lb. in.)	TYPE BD "L" max.	TYPE BD standard part no.*	TYPE BL "L" max.	TYPE BL standard part no.*
306:1	248	77	5.17	102A165	5.55	102A183
445:1	360	112		102A166		102A184
647:1	524	164		102A167		102A185
941:1	762	238		102A168		102A186
1166:1	896	280	5.34	102A194	5.72	102A204
1696:1	1305	407		102A195		102A205
2466:1	1900	550		102A196		102A206
3584:1	2760	550		102A197		102A207
5211:1	4000	550		102A198		102A208



WHEN YOU ORDER

***Part Number.** Complete part number consists of gearmotor part number from STANDARD PART NUMBERS table plus dash number from BASIC MOTOR PERFORMANCE table to designate armature. EXAMPLE: P/N 102A152-9 is a Type BD planetary gearmotor with 1⅞" flange; reduction ratio of 3.81:1; 27 v.d.c.; and a nominal no-load motor speed of 12,000 rpm.

Maximum Torque. Maximum intermittent torque is twice the rated value. Momentary stall or impact torque should not exceed five times the rated value, or internal damage to the geartrain may result. Maximum continuous output torque of the gearmotor is the product of the motor torque times the torque multiplier ratio. This value is limited by the maximum continuous torque.

For accessories and modifications, see Introduction to this catalog section, page 7.

Purafil

PRODUCT INFORMATION BULLETIN

128

CONTAMINANTS CONTROLLED BY

PURAFIL PELLETS

3550 BROAD ST., P. O. BOX 80434, CHAMBLEE, GEORGIA 30341 TELEPHONE 404-457-0827, 451-1678

The following is a list of compounds with estimates of probable reaction between the PURAFIL pellets exposed to low levels (1 - 10 ppm) of varied contaminants. Values are reported in pounds of contaminant removed per pound of PURAFIL:

COMPOUND	WILL IT REACT WITH PURAFIL?	#/# QUANTITATIVE DATA AVAILABLE
Acetone	Yes rapidly	.117 F
Methylethyl ketone	" "	.115 F
Acetylene	" "	.014
Acrolein	" "	.123 F
Allyl chloride	" "	.015
Arsine	Yes	.024
Benzene	No	.004
Styrene	Yes	.020
Carbon monoxide	Yes slowly	.017
Ethylene	" "	.004
Formaldehyde	Yes rapidly	.150 F
Acetaldehyde	" "	.016
Toluene	Yes slowly	.004
Xylene	" "	.005
Di ethyl amine	" "	.036 F
Tri ethyl amine	No adsorbed	.020
Mono methyl amine	Yes rapidly	.019
Di methyl amine	" "	.035 F
Tri methyl amine	No adsorbed	.018
Methyl chloroform	Yes rapidly	.012
Chloroform	" "	.008
Iodoform	" "	.016 F
Trichloroethylene	" "	.019 F
3 chloroprene	" "	.014
Carbon tetrachloride	No adsorbed	.005
Chloropicrin	Yes rapidly	.015
Stibine	" "	.011
Chlorine	No adsorbed	.123 F
Triarylphosphate	Yes slowly	.019 F
Ozone	No rapidly	Physical decomp. F
Nitric oxide	Yes rapidly	.032 F
Nitrous oxide	No adsorbed	.006
Nitrogen dioxide	Yes rapidly	.040 F
Peroxyacetyl nitrate (PAN)	" "	.026 F
Indole	Yes slowly	.018 F
Skatole	" "	.020 F
Phenol	Yes rapidly	.103 F
Methyl mercaptan	" "	.084
Nitro benzene	Yes slowly	.007
Pyridine	" "	.015
Phosgene	" "	.014

PURAFIL, INC., is a wholly-owned subsidiary of H. E. Burroughs & Associates

COMPOUND	WILL IT REACT WITH PURAFIL?	#/# QUANTITATIVE DATA AVAILABLE
Hydrogen	Slowly	.002
Butadiene	"	.004
Hydrogen sulfide	Yes rapidly	.076 F
Sulfur dioxide	" "	.110-.880 F
Iso propanol	" "	.055 F
Ethanol	" "	.060 F
Methanol	" "	.045
Methane	No adsorbed	.004
Propane	" "	.005
Butane	" "	.006
Butene -2	" "	.011
Butane diamine	Yes rapidly	.042 F
Ammonia	" "	.019 F
Butyl amine	" "	.022
Butyl mercaptan	Yes slowly	.103 F
Nicotine	" "	.162 F
Nicotinic acid	" "	.087
N-methyl pyrrolidine	" "	.102 F
Acetic acid	Yes rapidly	.055
Butyric acid	Yes slowly	.060
Caproic acid	" "	.090 F
Caprylic acid	" "	.100 F
Iso valeric acid	" "	.080 F
Ethyl acrylate	" "	.012
Amyl acetate	Yes rapidly	.012
Methyl acrylate	" "	.008

The normal wet chemistry stoichiometry of alkaline permanganate will not jibe with the results obtained. These are anomalies which result from the presence of reactive chemicals in the air upstream of the PURAFIL bed. In the presence of H_2S, SO_2 is removed much more efficiently than when it is present alone. Ammonia control in clean air is much less efficient than in the presence of acid gases (NO, SO_2, Cl_2). All oxidation reactions are enhanced by the co-action of alumina and permanganate. Some of these capacity data denoted "F" have been readjusted to reflect the field results obtained, since almost all contaminants are harder to control at 5, 10 to 15 ppm in the lab system than they are under the generally lower concentrations found in the field.

As a usable means of calculation it is noted that 1 ppm of contaminant removed from 1000 cfm of air continuously for thirty days corresponds closely to 50 gram molecular weights of the contaminant.

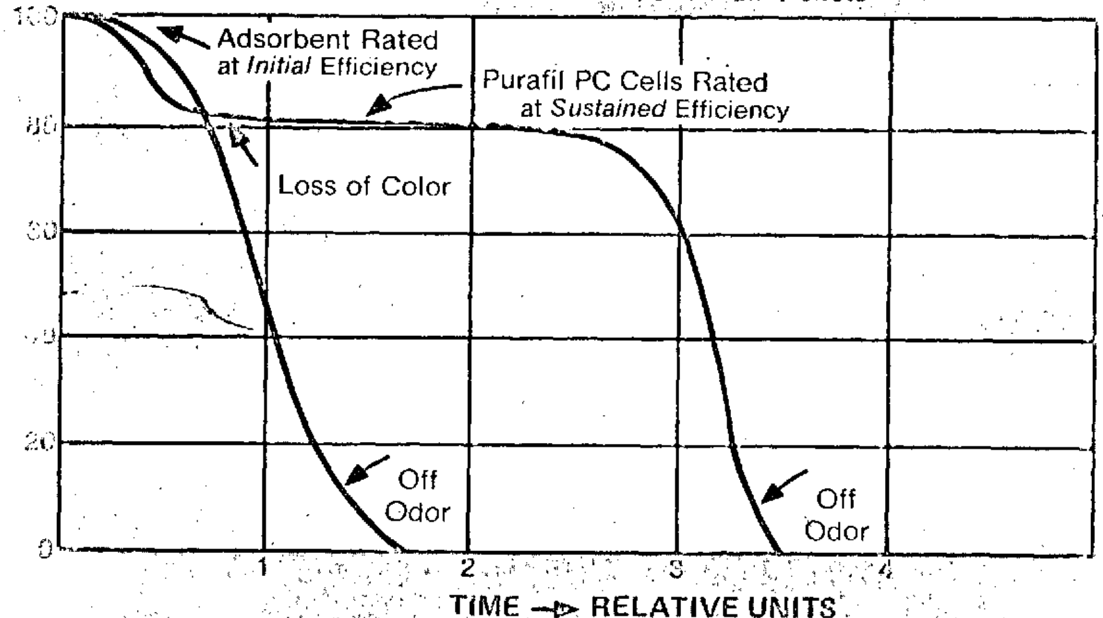
Hence, approximately 62 lbs. of PURAFIL will be required to remove 2 ppm of formaldehyde from 1000 cfm of air for one month.

A similar calculation for carbon monoxide indicates a requirement for about 500 lbs. of PURAFIL to control 2 ppm in 1000 cfm for a month. Field experience indicates that this use rate is incorrect, i.e. much to high by an order of magnitude for the composite represented by automotive exhaust.

HEB 1-3-72/2C

Performance Characteristics

Of Activated Carbon and 1/8" Purafil Pellets



Comparison based on equal air velocity and bed thickness
Contaminant 1ppm H_2S or Tobacco Smoke

As indicated on page 1, PURAFIL utilizes moisture in its odor destruction process. Even under extreme humidity conditions PURAFIL can be properly applied. In some rare cases where the relative humidity is less than 15%, water can be introduced to meet the odor destruction requirements. At close to 100% humidity in the air stream (approaching liquid phase conditions), condensation may settle on the pellets. This could reduce odor destruction if water droplets leach the permanganate and make it unavailable for reaction with the odor molecules. Proper system design avoids such limitations by introducing a small amount of heat, or dry air, and/or water separators just ahead of the PURAFIL filter.

The nature of the odor, mixture of odors, and the amount to be removed from the air are meaningful in some cases. PURAFIL pellets will react with and destroy almost all kinds of odors and odor mixtures, plus certain toxic gases which are odorless. A partial listing of reactive odors is given in the Appendix.

PRESSURE DROP

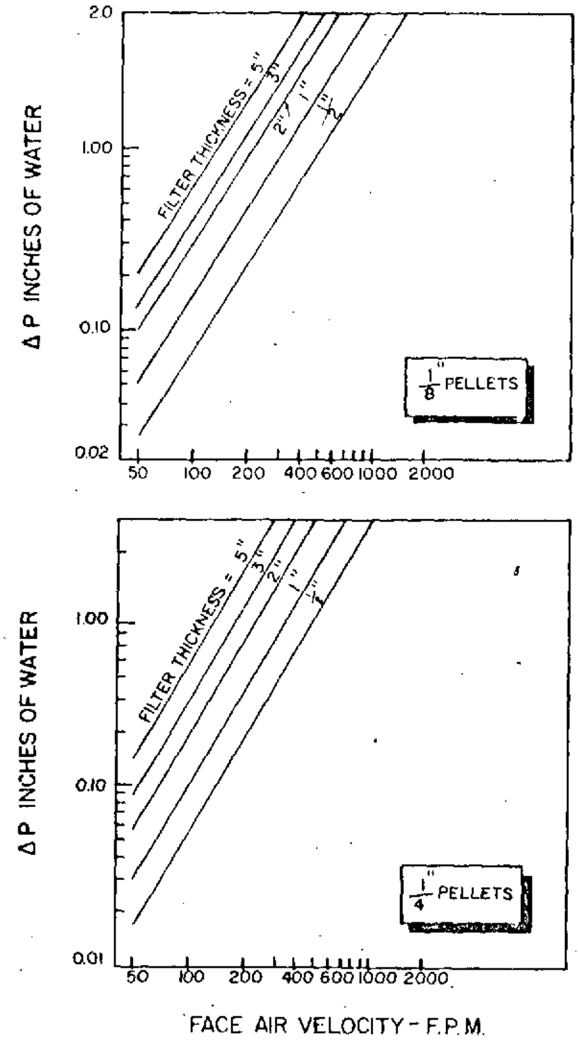
Pressure drop is the air flow resistance imposed by introduction of the PURAFIL filter into the recirculating air stream and/or the outside air intake. Generally reported in terms of inches (or decimals thereof) of water gauge measurement, pressure drop is related to the blower and motor size required to properly circulate the air through the room or building.

Pressure drop is affected by the same major variables of odor destruction efficiency: pellet size, filter thickness, and air velocity. Air velocity is related to the amount (volume) of air being transmitted through the ductwork. Optimum pressure drop and odor destruction efficiency can be achieved by proper system design.

Pressure drop data on the most popular PURAFIL pellet sizes are recorded in Figure 3, overleaf. The largest pellet size offers the least resistance to air flow.

FIGURE 3

PRESSURE DROP



The graphs show the relationship between pressure drop and filter thickness, sometimes referred to as bed depth. Doubling the bed depth in any pellet size doubles the pressure drop. The graphs also indicate that as air velocity increases, pressure drop increases, varying approximately as the square of the velocity.

The system designer must carefully consider all factors involved; in other words, to gain the advantage of highest efficiency may require a minor sacrifice in added pressure drop.

DC GENERAL PURPOSE BLOWER

58 CFM FREE AIR • 2.25" H_2O STATIC PRESSURE CUTOFF

This unit is a continuous duty blower assembly for operation from standard 28 vdc or rectified a-c power supplies in airborne or ground-based equipment. Brushes, which are treated for high altitude use, are rated for 250 hours life at 50,000 feet and 1000 hours at sea level. This unit meets applicable military specifications for vibration, shock, corrosion, temperature extremes, and operation in explosive atmospheres. Commercial or military finishes available. The motor is shunt wound for good starting torque and high overall efficiency. It can be made reversible by bringing out four leads rather than two.

MODEL B036
58 CFM

PART NUMBER
BD2011B-7

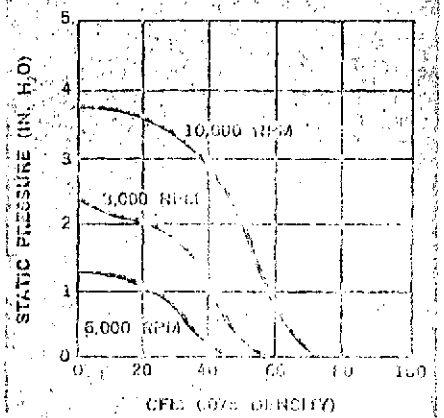
SPECIFICATIONS

SPECIFICATIONS	BD2011B-7
Capacity (free air) CFM	58
Input Voltage (volts)	28
Frequency (cps)	DC
Input Power (watts)	50
Current (amps)	1.8
Start Current (amps)	15
Speed (rpm)	8000
Weight (pounds)	1.6

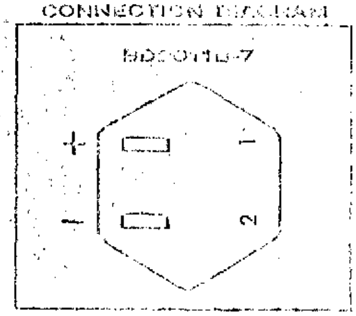
NOTE: Air delivery is as shown for 8000 rpm, can be wound for operation at other speeds and corresponding air delivery.

DESIGN OPTIONS for this model are available in the following categories: Compound or series shunt wound motors • Radio Noise Filters • Speed Ranges • Voltages • Temperature Ranges • Double-ended versions • Mountings • Finishes • Military or commercial specifications • Provisions for [illegible] (outlet flange or inlet rim) • CCW rotation is standard for this unit; CW available • [illegible] • Electrical Connections • For detailed option data see Technical Notes section.

AIR DELIVERY CURVE

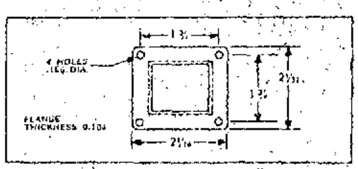


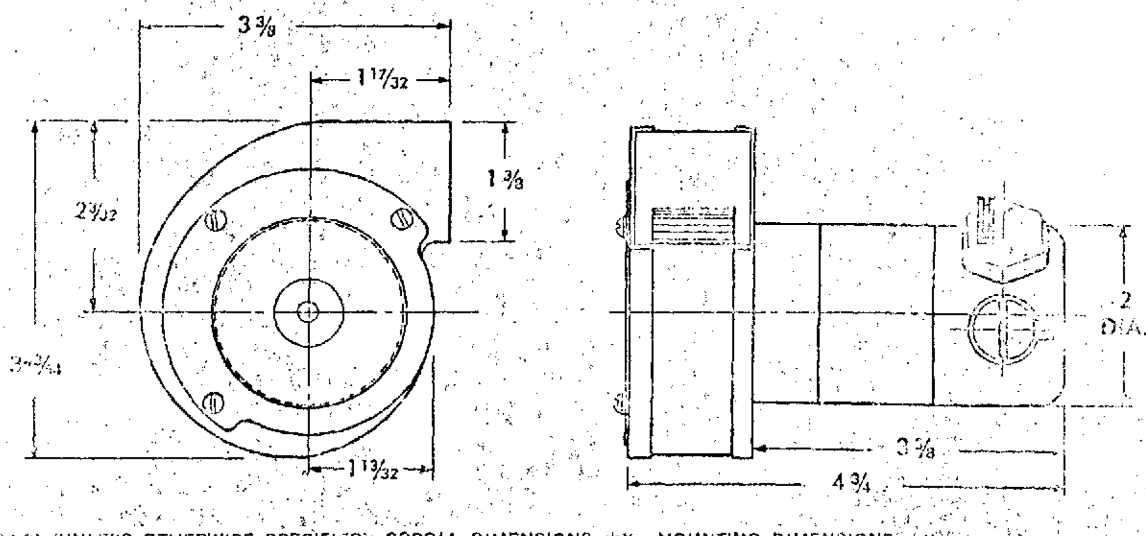
CONNECTION DIAGRAM



OUTLINE AND MOUNTING DIMENSIONS

FLANGE: OPTIONAL





TOLERANCES (UNLESS OTHERWISE SPECIFIED): SCROLL DIMENSIONS ±1/32. MOUNTING DIMENSIONS ±1/64.

PRECISE, WIDE-RANGE, RELATIVE HUMIDITY

Transducer

. . . Time-proven Hygrosensor combined with solid-state electronic circuitry provides a signal for telemetry, remote monitoring, voltage or current receivers, computers or data loggers.

This small, but highly sensitive transducer couples the well-known features of Hygrodynamics Hygrosensors with a solid-state transmitter to provide long-term accuracy and dependability. Since all signals are high level DC, no special cables are required; any four or five-conductor cable (two input and two or three output leads) should suffice with virtually no limit in length. Little input power is required.

True, proportional humidity output is assured by an exclusive, temperature-compensated circuit which automatically corrects the humidity signal for changes in temperature.

Under severe exposures, in meteorological or other applications subject to precipitation or condensation, the sensor should be protected by weatherproofing and by placing the unit in a specially designed weather shelter available as accessory equipment.

ORDERING INFORMATION

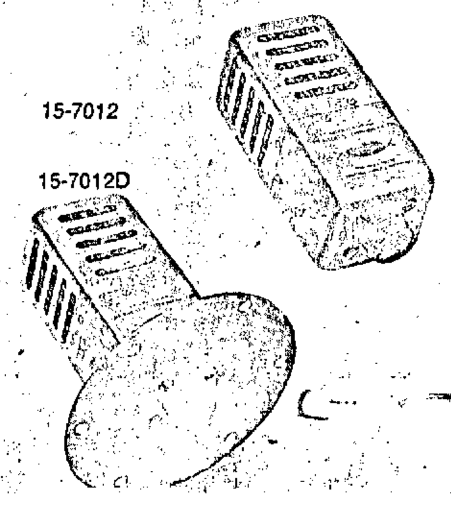
15-7012 Humidity Transducer, 10 to 99% R.H. range between 40° and 120° F ±3% R.H. accuracy.

15-7012D Humidity Transducer, with 5″ dia. duct-mounting plate installed.

Humidity Transducer, as above, with weatherproof sensor protection, add suffix "W" to Cat. Number.

15-7012

15-7012D



SPECIFICATIONS
15-7012 R.H. TRANSDUCER

Humidity Range
10% to 99% R.H. (Limited to 100° Dew-Point for temperature over 110° F, dry-bulb)

Accuracy
±3% R.H. between 40° and 120° F

Input — Voltage, Current
8 to 32 volts DC, 30 milliamperes

Output

Voltage
0-5.4 volts DC, adjustable proportional to 0-100% R.H., nominal output. Allowable load: 200 K ohms or higher resistance across voltage output terminals

Current
0-150 microamperes, nominal, proportional to 0-100% R.H. Allowable load: up to 1000 ohms resistance across current terminals

Voltage & Current
Simultaneous output permissible, if voltage output exceeds 2 volts

Output Ripple
0.5% at approximately 800 Hz

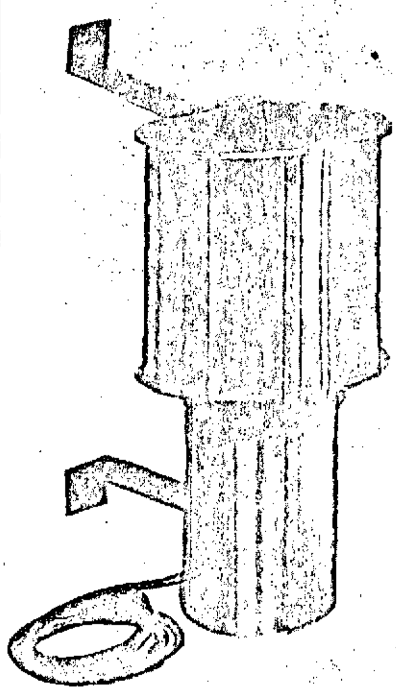
Electrical Protection
Protection provided against accidental input voltage polarity reversal

Size
Body: 2¼ x 2¼ x 4½ inches (19 cu. in.) 5¼ in. long overall

Finish
Gold anodized aluminum case

Weight
10 oz. net; 2 lbs. shipping

Connector, Input-Output
Type MS-3102R-14S-6P. Mating cable connector, Type MS-3106A-14S-6S and cable clamp, 3057-6, supplied



PROTECTIVE DEVICES FOR SENSING ELEMENTS

15-6175 Weather Shelter—Fan-ventilated device used in outdoor locations for protection against rain, dust, snow and meteorological radiation. Includes a washable air filter and circulating blower fan. Operates on 115V, 50/60-cycle current. Fan is rated at 55-watts, 0.7-amperes. Fan motor is rated at 3050-rpm, 60-cycles; will run at 2450-rpm on 50-cycles.

Battery-Powered

RECORDING SYSTEM

For mobile systems such as trucks, railroad cars etc. a recording system can be provided by combining a 12V D.C. recorder (similar to unit used in above) with the 15-7012 Transducer described above. Submit complete application details to Aminco Sales Engrg. Dept. for recommendations.

Operating Instructions

CONTENTS

15-7012

HUMIDITY TRANSDUCER

Instruction No. H-170

Applies to instruments with serial number 926-1 and higher.

C + 2

1. SPECIFICATIONS—RELATIVE HUMIDITY TRANSDUCER, 15-7012

Humidity Range	10% to 99% R.H. (Limited to 100° Dew-Point for Temperatures over 110° F, dry-bulb).
Accuracy	±3% R.H. between 40° and 120° F.
Input: Voltage, Current..	8 to 32 volts DC. 30 milliamperes, at any voltage from 8 to 32 volts.
Output: Voltage*	0 to 5.4 volts DC, adjustable, proportional to 0-100% R.H. nominal output. Maximum allowable load: 200 K ohms resistance across voltage output terminals.
Current	0-150 microamperes, nominal, proportional to 0-100% RH Allowable load: 1000 ohms.
Voltage and Current	Simultaneous output permissible (if required voltage output exceeds 0-2 volt range)
Output Ripple**..........	Approximately 0.5% at approximately 800 Hz (cps)
Electrical Protection.....	Protection provided against accidental input voltage polarity reversal.
Size....................	Body: 2 1/4 x 2 1/4 x 4 1/2 inches (19 cu.in.), 5 1/4 in. long overall.
Finish	Gold Anodized aluminum case.
Weight	10 ounces net; 2 pounds shipping
Connector: Input-Output ..	Type MS-3102R-14-6P. Mating cable connector, Type MS-3106A-14-6S and cable clamp 3057-6, supplied.
Mounting Position........	Any (see installation)

* For millivolt output, see paragraph VI, B, 2, b and Fig. 4, page 7.
** If used in connection with high-speed, sampling-type readout, additional filtering might be required. Consult factory.

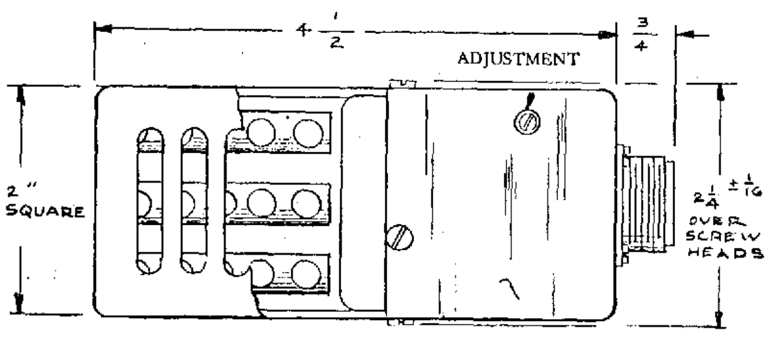


Figure 1.
Dimensional Drawing
Ref. B24-6038A

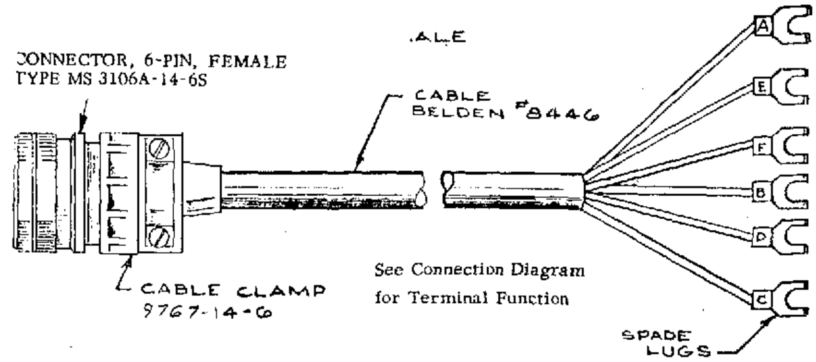


Figure 2.
Cable Assembly Detail
Ref. B24-6038A

II. INSPECTION

A. Receiving Condition Report

1. If damage is discovered upon unpacking the instrument, an immediate request should be made to the delivering carrier to perform an inspection and prepare a concealed damage report.

2. Concurrently, the extent of the damage should be reported to Hygrodynamics giving instrument model number and serial number on the nameplate so that action may be initiated to replace damaged parts, or to issue instructions for the return of the apparatus, if such is deemed necessary.

III. DESCRIPTION

A. Transducer Assembly

1. The 15-7012 Humidity Transducer consists of a multiple cell humidity sensor and a transmitter (converter) integrally mounted to provide a current or voltage output signal proportional to relative humidity when the unit is connected to a D.C. power supply.

B. Humidity Sensor

1. The humidity sensor in the unit is made up of a number of Hygrosensor cells combined in an electrical network to enable measurement over a wide range of relative humidity.

2. Each cell consists of a plastic rod, a dual winding of precious metal wire, and a coating of moisture-sensitive compound, and is contained in an individual, perforated, plastic jacket. The cells are collectively mounted in a common base and protected by a ventilated cover against physical damage.

C. Measuring Circuit

1. The measuring circuit is contained in the base of the transducer assembly with power input and signal output connections through a common 6-terminal male MS connector.

IV. PRINCIPLE OF OPERATION

A. Sensor Operating Theory

1. Operation of the sensor is based on the ability of a hygroscopic film to change its electrical resistance significantly and rapidly with small changes in relative humidity. Each of eight cells in the electrical sensor network covers a narrow span of relative humidity overlapped by the span of the adjacent cell. These cells, linked with precision resistors in a ladder network, comprise the sensor designed to cover the full span of relative humidity.

B. Circuit Theory

1. The circuit in the base of the Transducer consists of an input voltage regulator, a transistor oscillator, a temperature compensating circuit, and the relative humidity measuring network.

2. The oscillator provides the necessary AC voltage at a frequency of approximately 400 cps, through a transformer, to the sensors. The output of the sensor network is rectifiedby a full wave bridge and combined with a temperature signal, as sensed by a precision thermistor located in the humidity sensor compartment. (This temperature signal is necessary to compensate for the temperature effect on the sensor). The rectified and temperature-compensated signal is then filtered and provides a current or voltage output signal for a suitable readout unit.

V. OPERATING LIMITS

A. General -- The sensor is a humidity-sensitive variable resistor whose response is governed by a hygroscopic coating of lithium chloride and/or lithium bromide on a plastic coil form with bifilar windings of palladium. In normal, clean atmospheres, the useful life of the sensor is limitless. However, the sensor's calibration can be altered by certain contaminants, by changes in the concentration of the hygroscopic salt, or by replacing an individual sensor in the wrong socket. Mention is made of the operating limits, because certain conditions, with regard to sensor exposure, must be taken into consideration when selecting sensor and mounting location before installation.

B. Humidity and Temperature Exposure *

1. Standard Transducer

a. 40° to 110°F. The transducer may be used in atmospheres up to near saturation in this temperature range, provided condensation does not occur on the Hygrosensors.

b. 110° to 120°F. The transducer may be exposed to temperatures in this range, provided dew-point temperatures do not exceed 100°F, and provided condensation does not occur.

c. Above 120°F. It is not recommended that the transducer be exposed to temperatures exceeding 125°F. If the air or gas has a low, absolute humidity, pre-cooling to limits of a and b above may enable measurements. Facilities for tempering air under these conditions are available from Hygrodynamics.

d. Below 40°F. The transducer may be exposed to very low dry-bulb temperatures, however, the output signal will not necessarily be directly proportional to relative humidity when operating at these low temperatures.

e. For operating below 40°F and above 120°F always consult factory.

* CAUTION: Never operate the transducer in ambients above 125°F. Refer to paragraph V. H. for additional temperature considerations.

2. Weatherproof Transducer (Identified by suffix W or WP to Catalog number)

a. This model has been fabricated with a protective, weatherproof covering over the cells in the sensor compartment to minimize the damage due to exposure to condensation.

b. The limitations of the Standard Transducer enumerated in 1 above apply, except with regard to the possible, accidental or occasional exposure to condensation.

c. The protective covering provides nominal protection against accidental condensation only. For outdoor applications, the transducer should be placed in a weather shelter available from Hygrodynamics.

C. Contaminants

1. Physical Contaminants -- Always use a filter to protect the transducer from dusty or dirty atmospheres (See section VI, paragraphs A, 2, d). The sensor of the transducer should be protected from contact with liquid water or condensation as pointed out in paragraph A above.

2. Chemical Contaminants -- Chemicals, such as mercury, acids, sulfides, etc. cause a permanent shift in calibration. Alcohols, ammonia, glycols, etc. cause a temporary poisoning, however, the sensor will return to normal when removed to a clean atmosphere.

D. Pressure and Vacuum

1. Sensors have been successfully used at 10,000 psig, and have withstood exposure to vacuum of less than 1 mm Hg (and for brief periods as low as 10^{-3} mm Hg) without permanent loss of calibration. If use under these conditions is contemplated, request information Sheet No. 4 " Measurement of Relative Humidity in Vacuum."

E. Gas Velocity

1. Sensors have successfully withstood several hundred-mile-per-hour velocities. However in all high velocity gas streams a deflection shield is recommended as protection against air-borne particles.

F. Electrical Hazzard

1. As with any electrical humidity sensor, the sensitive surface is exposed and cannot meet Class 1, Group D explosion-proof requirements; however the element is sparkless and draws little current (maximum 100 microamperes) and does not, itself, generate heat.

G. Electrical Power Requirements

1. The transducer is designed for operation with an input from 8 to 32 volts D.C.

NOTE: Under normal operating conditions requiring inputs less than 18 volts heating effect is negligible, however when used with power input near or above 18 volts, the regulating circuit of the transducer may heat up. Therefore, the base of the unit should be mounted directly onto a metal surface or heat sink for dissipating heat generated, to minimize psychrometric error and prevent exceeding maximum recommended temperature of 125°F.

H. Heat

CAUTION

Never permit the transducer to generate heat above 125°F, nor operate in ambients above 125°F.

VI. INSTALLATION

A. Selection of Location

1. Suitable Location

a. Install the transducer in an area where the air will be representative of the entire space.

b. If semi-stagnant conditions exist, place a small fan, near the location selected for the transducer, to draw (not blow) air over the sensor.

2. Locations to Avoid

a. The transducer should not be located near entrance doors, cold ducts, nor near ducts discharging warm moist air into a cooler space.

b. "Liquid" water collecting on the hygroscopic element of the sensor will change its calibration. It is suggested that a small fan be used to draw air over the sensor to reduce likelihood of condensation when such conditions may exist.

c. Avoid locations where radiant heat from heaters, lights, motors, warm walls, etc., will affect temperature of the atmosphere surrounding the sensor.

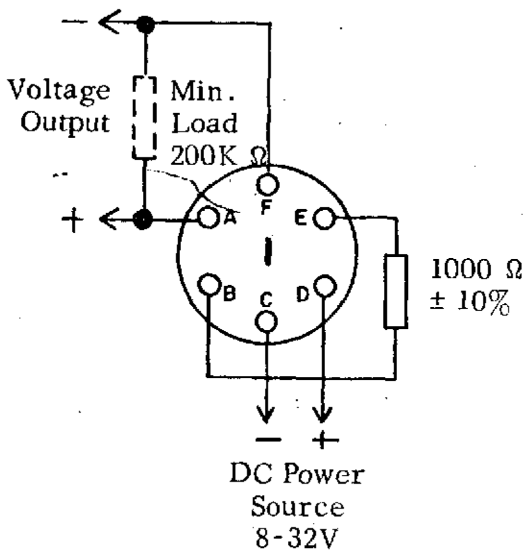
d. If the transducer must be exposed to atmospheres containing dust or soot, protect the sensor portion with a screen:

(1) Use 200 x 200 mesh screen for large particles.

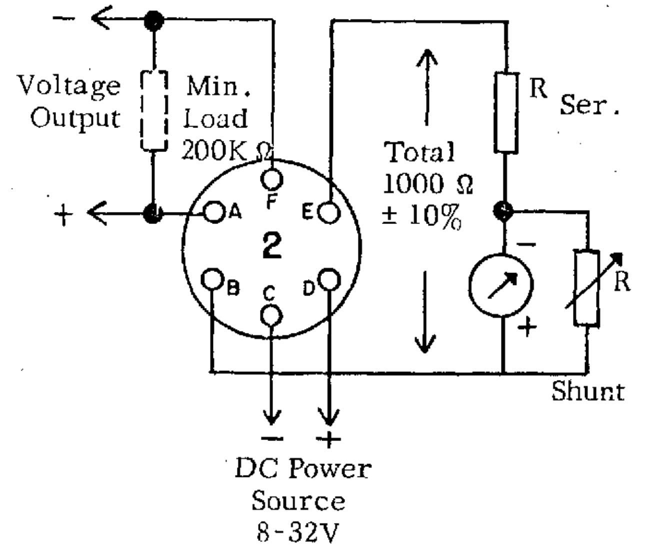
(2) For fine particles or extremely dirty or oily atmospheres, use nylon, paper facial tissue or moisture-pervious cellophane. These protective devices reduce speed of response, but will extend the useful life of the sensor when exposure to these adverse conditions is necessary.

15-7012 HUMIDITY SENSOR-TRANSMITTER
INPUT - OUTPUT CONNECTIONS

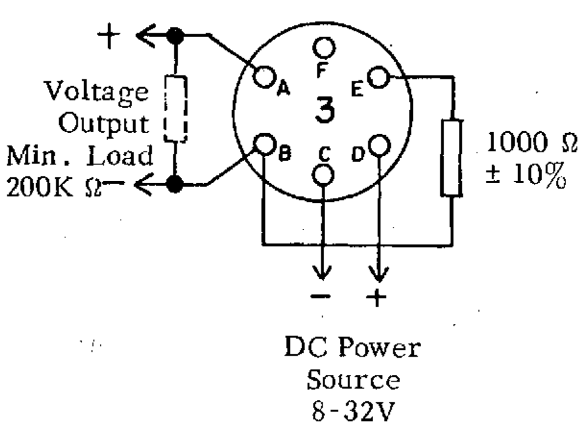
FOR VOLTAGE OUTPUT
0-2V through 0-5V



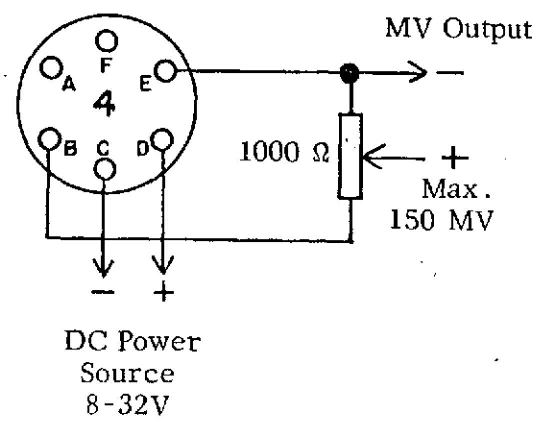
FOR VOLTAGE AND/OR CURRENT OUTPUT
0-2V through 0-5V and Min. 150μA



FOR VOLTAGE OUTPUT
0-0.5V through 0-3V



MILLIVOLT OUTPUT
0-150mv or Less



These connection diagrams apply to units bearing serial nos. 926-1 and up.
NOTE: External components not supplied with instrument.

3. Mounting (any position)

a. The unit is not position-sensitive and may be oriented in any practical position.

(1) The 15-7012 may be suspended by its own cable.

a. Mount on metal plate or heat sink if input power exceeds 18 volts.

(2) The 15-7012D has a permanently attached 5" dia. aluminum mounting plate 1/16" thick for duct or through-wall mounting. Requires a 2 7/8" minimum diameter hole through the mounting surface. Six 1/2" (#25 drill) mounting holes are spaced 30° apart on 4 1/2" dia. centers.

B. Cable Assembly

1. Connecting cable is not supplied with the transducer. The cable is assembled by connecting a 6-conductor cable (Belden #8446, or equivalent) to the 6-pin female connector, MS 3106A-14-6S and cable clamp 3057-6 supplied with the unit.

a. Solder cable to connector pin terminals as described in the connection diagram, Figure 3.

b. Terminate leads on other end of cable to mate with power input source and with the current or voltage read-out device.

2. Connect cable connector with the transducer and connect other end of cable to the power supply and the current or voltage input device.

a. Power. Using an 8 to 32 volt D. C. power supply, connect lead "C" to the negative terminal and lead "D" to the positive terminal. The transducer is provided with a safeguard against accidental damage due to inadvertent input voltage polarity reversal.

b. Millivolt Signal. The current output can be used with a 1000 Ohm potentiometer to drive devices requiring millivolt inputs.

NOTE: It is necessary to use a potentiometer to adjust the millivolt output, since the full scale current value may vary from unit to unit and is not adjustable.

VII. OPERATION

A. Initial Adjustment - The output signal should be adjusted to match the input of the signal receiver. This is a full-scale adjustment, and no further adjustment is necessary after initial field setting for the receiver used.

1. Voltage Input Device - Adjust as outlined in paragraph B steps 1 to 4, (omit 5), and continue with steps 6 to 8.

2. Current Input Device - The output of the transducer when wired in accordance with installation instructions, VI.B.1.a., is fixed at approximately 150 microamperes for a nominal 100% R.H. reading. To adjust the full scale signal, the input device should be shunted with a variable resistor, and adjustment made as outlined in paragraph B, steps 1 to 3 (omit 4) and continue with steps 5 to 8, following:

B. Adjustment Procedure

1. Remove the four sheet metal screws on the sides of the case and take off the vented cover.

2. Note that the sensor assembly consists of 8 sensor cells, and that both sensor and sensor location are color-coded in a clockwise direction as follows: brown, red, orange, yellow, green, blue, violet, and gray. The center unit, similar in appearance to the humidity sensor cells, except that it is potted, is a resistance set-plug. The center socket is non-

operative, serving only as a holder for the set-plug.

3. Replace the gray color-coded sensor with the "potted" set-plug, stored in the center socket, inserting it into the socket oriented so that the color-coded patch on the plug is pointing toward the corner of the case. All other sensors may be left in place.

4. For Voltage Input Device - Remove the 6-32 screw located on the base, below the nameplate, and insert a small screw driver to adjust for full-scale output voltage. This corresponds to a nominal 100% R.H.

a. Replace #6-32 screw. Continue with Step 6.

5. For Current Input Device - The maximum current available from pins B and F is approximately 150 μA at 100% R.H. This current is not adjustable internally. Any current-actuated device can be operated on this output as long as the maximum current required is not over 150 μA. If less current is required for the device, the current can be reduced to any level by a proper, adjustable, shunting resistor, as long as the combined value of device resistance and shunt does not exceed 1000 ohms. If less, make it up with a series resistor to approximately 1000 ohms ±10%.

6. Remove the set-plug from the gray socket and insert it into its center mounting socket (no particular orientation is necessary).

7. Insert the gray color-coded cell in its socket making sure that the color-code patch on the cell faces the corresponding color mark on the base near its socket.

8. Replace the vented cover and secure in place with the four mounting screws.

9. Shorting any one of the pins can not damage the instrument.

C. Interpretation of Signal

1. When connected and adjusted according to the foregoing, the output signal, voltage and/or current, will be directly proportional to relative humidity within the ranges listed in the specifications. For example: if the receiver has a 0-100 linear scale, the scale reading would correspond directly to relative humidity sensed; if the receiver has a 0-5 linear scale, such as 0-5 V DC, the indication would be converted to relative humidity by multiplying the scale reading by 20.

VIII. MAINTENANCE

A. The transducer is part of a high precision measuring system, therefore, it is absolutely necessary that it be treated with care during installation as well as in location and use. Any failure to observe and follow the instructions resulting in damage to the unit will nullify the warranty.

B. A small accumulation of lint or dust may collect on the sensors if the transducer is used continually in an exposed location. This accumulation will not seriously affect sensor calibration and no attempt should be made to remove this coating since injury to the sensor may result.

C. The transducer sensor is a composite of a number of individual plug-in cells. These plug-in cells should not be removed except to clean the mounting base. If removal is necessary, the color code and orientation of the mark should be noted and the cells returned to the proper socket with the color coded patch on the cell facing the color-coded mark on the base. If any cells are omitted or inserted in the wrong socket, the humidity output signal will be seriously changed.

D. Precise, humidity, field calibration of the transducer is extremely difficult. Therefore, after extensive use, if it is desired to have the unit checked for proper humidity calibration, it may be returned to the factory for a check, a service for which a nominal charge is made. Keeping a spare transducer handy is the most practical means of checking calibration by comparing readings periodically, and to use as a relief unit while the service unit is being checked.

E. If the transducer is beyond its calibration tolerance, it is not repairable, except for replacement of the individual sensors.

IX. WARRANTY

A. Conditions of the Warranty

1. Please note carefully the provisions of the written warranty supplied with this equipment and be sure to fill out the registration certificate to validate the warranty.

2. This warranty will not apply if the transducer has been tempered with or altered in any way after leaving the factory or if the transducer is used other than as outlined in this instruction.

3. Hygrodynamics, Inc. assumes no liabilities for resultant damage of any kind arising from the use of the product. This warranty being expressly in lieu of all other warranties expressed or implied, and all other obligation, either to the original purchaser or to any other person.

X. STANDARD ACCESSORIES

CATALOG NO.	DESCRIPTION	SOURCE
	AN-3057-6 Cable Clamp	Electronic Supply House
	Input-Output, 6-pin, female connector, for cable, Type MS-3106A-14-6S	Electronic Supply House

XI. OPTIONAL ACCESSORIES

HYGRODYNAMICS CATALOG NO.	DESCRIPTION	SOURCE
88-901-66	Connecting Cable Belden #8446 or Equiv. Specify Length.	Electronic Supply House
46-008-05	Duct-Mounting Plate, 5" dia. 1/16" thick aluminum with six 1/4" dia. holes spaced 30° apart on 4 1/2" dia. centers.	Hygrodynamics

7.5 Miscellaneous Analyses

7.5.1 Alternate Approaches

In addition to the basic DRY-JOHN type concept selected for the Solids subsystem, other alternate collection and sampling concepts were considered. On of these alternates is shown in block diagram form in Figures 7.5-1. The subsystem shown in Figure 7.5-1 is essentially a modified GE HYDRO-JOHN approach having both a sampling and mass measurement capability. This general approach was further examined as noted in PIR 1R62-73-106 (included in Section 7.5.2 below). Although attractive, this approach was finally rejected as incompatible with SHUTTLE.

7.5.2 Analyses

The following internal GE memoranda are included as supplemental information considered of general interest in relation to the ABSS Solids subsystem:

a. GE PIR 1R62-73-105, "Load/Elongation Properties of Feces".

b. GE PIR 1R62-73-106, "Mass Measurement Accuracy".

c. GE PIR 1R62-73-115, "Microbiological Considerations".

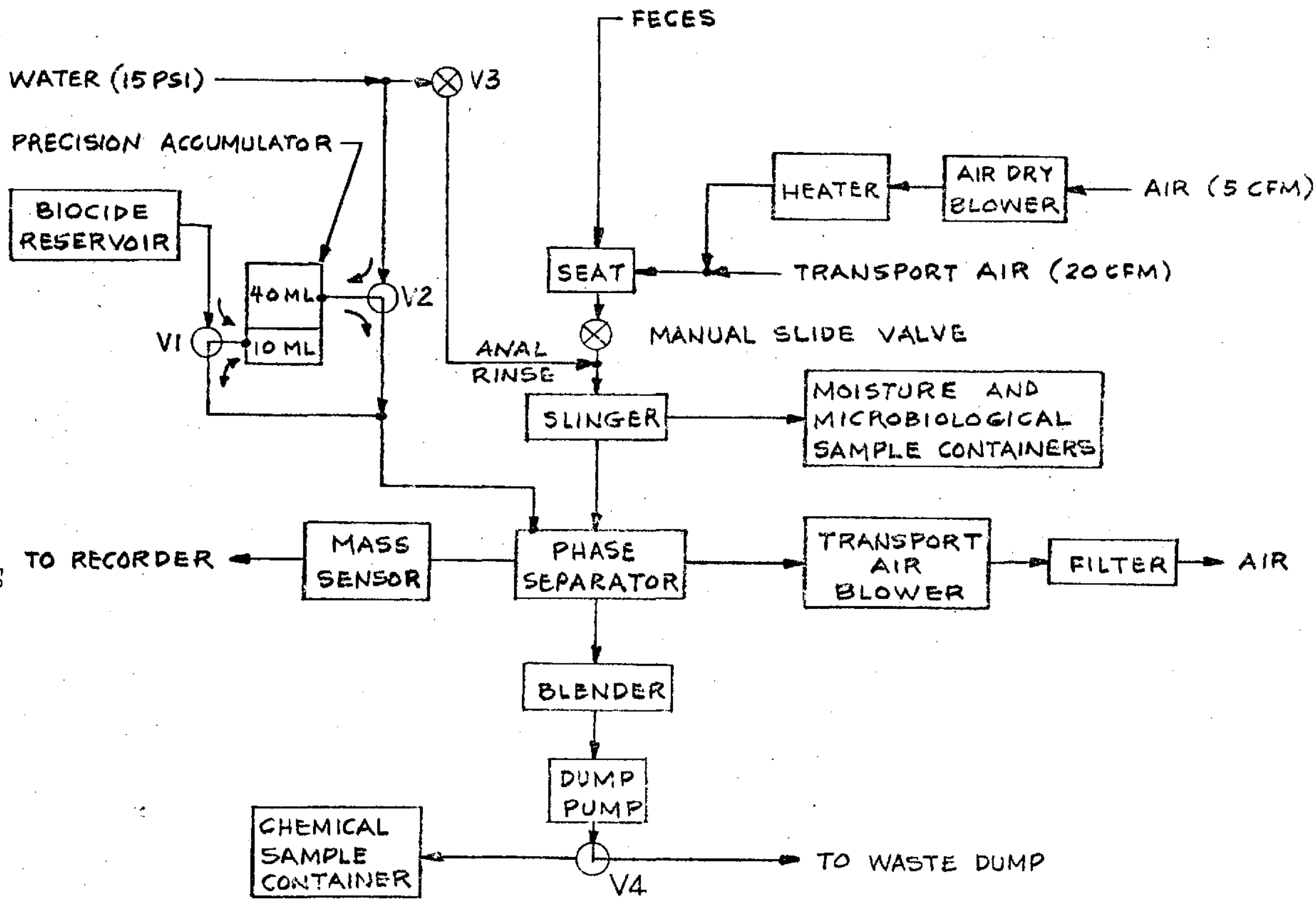


FIGURE 7.5-1 SOLIDS SUBSYSTEM BLOCK DIAGRAM (HYDRO-JOHN TYPE)

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LOAD/ELONGATION PROPERTIES OF FECES

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Figure 1 summarizes exploratory ROM test data from one feces sample. The feces moisture content was not determined. However, the sample had a firm consistency and thus the moisture content was probably about 75%. The force required to separate the 1" diameter brass rod from the feces was determined by a beam balance arrangement. Note that rupture of the sample occurred near but not at the sample/brass rod interface. The rate of loading was variable but averaged an estimated 4 gram increment every 10 seconds. The corresponding sample elongation was recorded for each increment (or multiple). Figure 2 summarizes comparative test data using cream style Skippy Peanut Butter as the sample.

As might be expected, the length of the sample (dimension ℓ on Figures 1 and 2) has a decided influence on the load/elongation relationship. Note that no definite yield point apparently exists. However, and particularily for peanut butter, an elastic region (stress proportional to strain) is apparent. Based on the apparent ultimate strength, the work required to rupture the sample, i.e., separate the brass rod from the sample, was calculated as follows:

ℓ	ESTIMATED ROM WORK REQUIRED	
	FECES	PEANUT BUTTER
.125 in.	5.45 gm-cm/cm^2	5.45 gm-cm/cm^2
.25 in.	4.0	3.2
.50 in.	3.8	3.2

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J. K. Mangialardi
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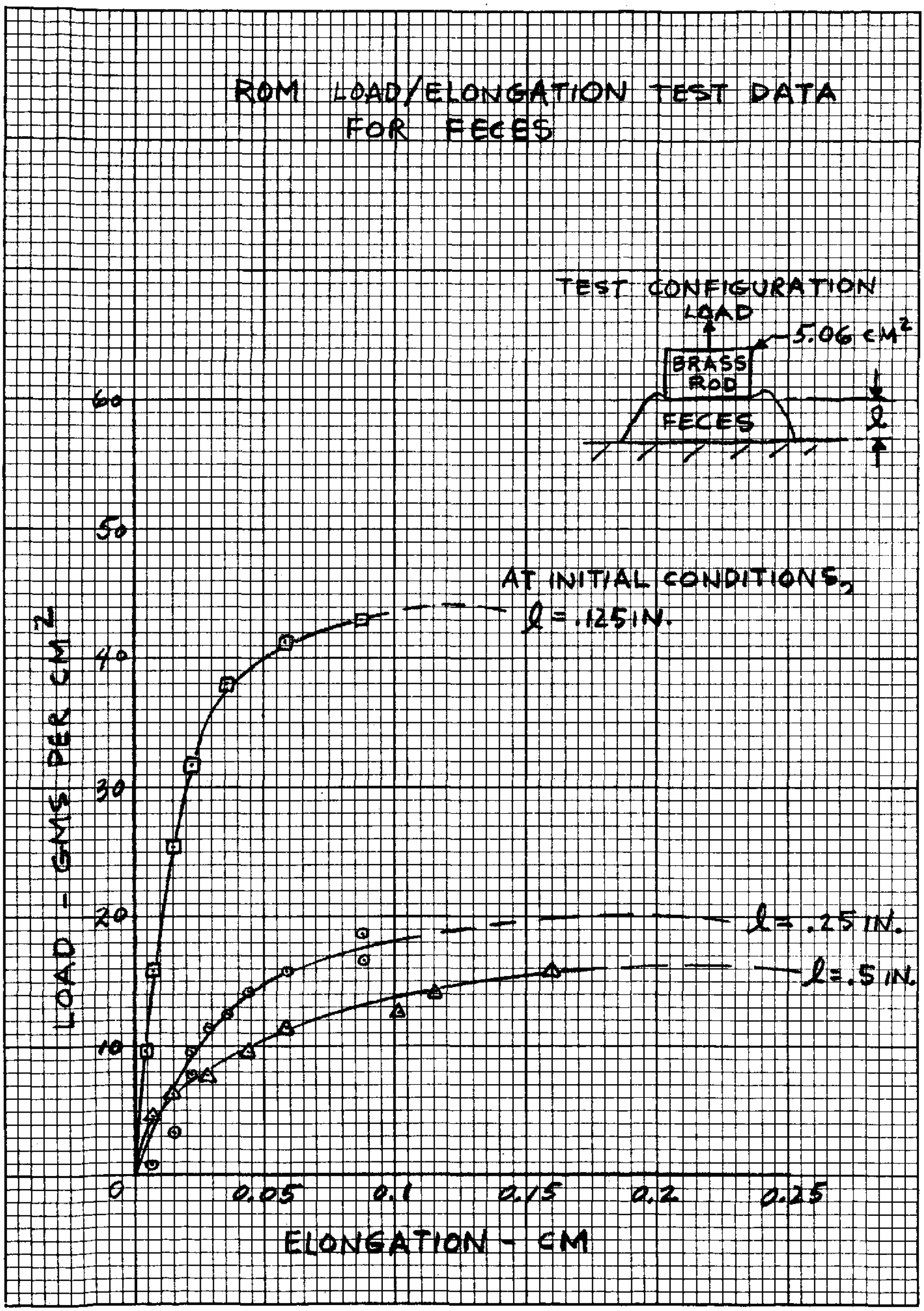
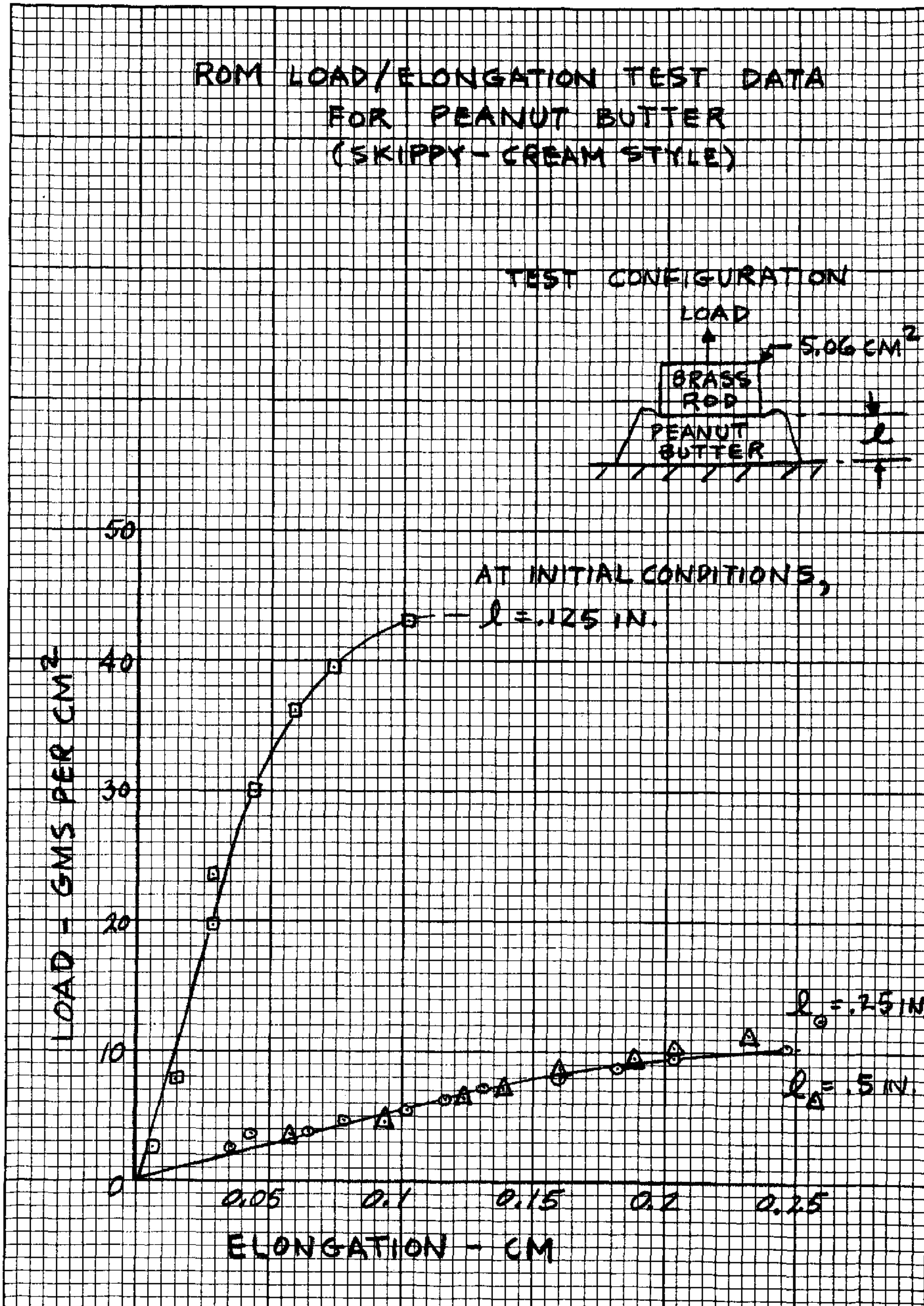


ROM LOAD/ELONGATION TEST DATA
FOR FECES
TEST CONFIGURATION
LOAD
5.06 CM²
BRASS ROD
FECES
l
AT INITIAL CONDITIONS,
l = .125 IN.
l = .25 IN.
l = .5 IN.
LOAD - GMS PER CM²
ELONGATION - CM
0
10
20
30
40
50
60
0.05
0.1
0.15
0.2
0.25


ROM LOAD/ELONGATION TEST DATA
FOR PEANUT BUTTER
(SKIPPY-CREAM STYLE)
TEST CONFIGURATION
LOAD
5.06 CM²
BRASS ROD
PEANUT BUTTER
ℓ
AT INITIAL CONDITIONS,
ℓ = .125 IN.
ℓ○ = .25 IN
ℓΔ = .5 IN.
LOAD - GMS PER CM²
0
10
20
30
40
50
0.05
0.1
0.15
0.2
0.25
ELONGATION - CM

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2/13/73		ABSS SOLIDS S/S	

SUBJECT

MASS MEASUREMENT ACCURACY

INFORMATION REQUESTED/RELEASED

1.0 REQUIREMENTS

A design goal for the ABSS Solids Subsystem is an automated capability for measuring the weight of feces and vomitus within + 2% of the actual value. The quantity to be measured varies from an undefined minimum to 250 grams fecal material per defecation and up to 1000 ml maximum of soild/liquid waste per defecation. Vomitus volume may vary up to 1000 ml also. From the Bioastronautics Data Book, NASA publication SP-3006, page 219, a normal lower limit for fecal material appears to be about 50 grams per defecation.

2.0 RELATIONSHIP TO COLLECTION METHOD

Feces mass measurement can be accomplished by a number of techniques; however, the technique of choice is highly dependent on the feces collection method employed as shown by Table 1. In bag type collection systems, an air permeable bag is used to trap the ejected feces and vomitus. Air permeability is required in order that a transport air flow can be generated to convey the feces or vomitus into the collection bag. The entire quantity of feces or vomitus is collected, an advantage particularly for small input quantities. The bag is then closed manually, removed from the collection system and manually transported to a weighing device, an SMMD for example. A significant problem is the positive retention of liquid waste material in the bag, both at the closure and at the permeable portion of the bag. Although conceivable that the mass could be determined by an in place device, removal to an external (to the system) mass measurement device such as the SMMD would appear preferrable. In either case, the bag must ultimately be removed, real time samples obtained and then sealed in a non-permeable container for storage. This handling process is offensive and potentially hazardess. Only minimal overall automation can be achieved.

The Dry-John type collection system is potentially very attractive. In this collection concept, the ejected feces or vomitus is conveyed by the transport air into a high speed rotating element called a slinger. The solids/liquids are then accelerated radially outward by the slinger. This action causes a delta change in slinger rpm and power input which is proportional (directly or integrated over the time period) to the weight of the incoming soild or liquid. This delta

R. W. Murray
J. K. Mangialardi
G. L. Fogal (3)
F. S. DiSanto

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change can be accentuated by judicious selection of slinger motor, e.g., low inertia, marginal torque. A major unknown is measurement repeatability due to the random nature of slinger and solids/liquids impact conditions. Laboratory test data is needed to confirm or deny this method of mass measurement. Aseptic collection of real time samples is relatively easy to accomplish. Mechanical probes may be placed adjacent to and in the path of material from the slinger. However, sample size will be proportional to the total input. Also, large samples are impractical to collect by this means.

In Hydro-John type collection systems, the ejected feces or vomitus is carried by the transport air into a chamber containing a rotating impellor, i.e. into a phase separator. A known amount of water is then added and mixed with the feces or vomitus to form a slurry. The mass or volume of the slurry is then measured to indirectly determine the quantity of feces or vomitus. Several methods are available. For example, the slurry may be pumped out of the phase separator thru an integrating flowmeter to determine volume. Volume may also be determined by positive displacement methods such as used in the USCS development, NASA Contract NAS9-10741. Or mass may be sensed directly by using the phase separator as a constant speed centrifuge and measuring the resulting static pressure generated.

A Hydro-John type collection system appears to best meet the ABSS requirements. Automation is readily accomplished; user acceptance is high. Several potential mass sensing methods are available. By adding a slinger element, real time "solid" samples can be collected as well as relatively large slurry samples. In both instances, however, sample sizes are proportional to the total input.

3.0 MEASUREMENT ERROR ANALYSIS

3.1 USCS POSITIVE DISPLACEMENT

The precision accumulator used to measure urine volume in the USCS can be used to measure slurry volume. Figure 1 shows the location of the device in the Solids Subsystem. Figure 2 shows the estimated measurement error for the expected range of feces and vomitus input. Accuracy is within about ± 2% for waste inputs over about 50 grams and, as shown, is approximately equivalent to that obtained for the SMMD. For these calculations, the estimated error was assumed to be the RMS sum of the accumulator error plus the error in adding the 200 ml volume of water to form the slurry. Both errors are based on test results with the USCS.

3.2 INTEGRATING FLOW SENSOR

Figure 3 illustrates use of an integrating flow sensor. Figure 4 shows the estimated measurement errors for a flow sensor having an error of ± 1% (of the reading). This assumes that the geoscience, Ltd. thermal flow sensor for monitoring urine can be successfully adapted to a slurry composition. As above, the total error was assumed to be the RMS sum of the flow sensor plus the error in adding the 200 ml to form the slurry. To approach an overall error of ± 2% a flow sensor error near ± 0.1% is evidently required. Figure 5 shows results for a ±0.5% (of full scale) flow sensor for both single and dual range installations.

3.3 CENTRIFUGE

By adding a pressure sensor and speed control, the phase separator may be used as a centrifuge to measure mass of the slurry, Figure 6. Estimated measurement error was calculated for a number of variations with results shown in Figures 7 thru 11. In each case the total error was assumed to be the RMS sum of the error in adding the 200 ml of water to form the slurry, the pressure sensor error and the error resulting from speed variations of the phase separator. Phase separator speed was assumed to be within ± 0.1% of the desired rpm, an accuracy value readily obtained in commercial hardware (and used in the USCS program). The error for a Setra-Systems Model 237 pressure sensor was assumed for the pressure sensor; a value of ± 0.2% of full scale was used. Additional calculation details are contained in enclosure A.

Referring to Figures 7 thru 10, it is apparent that adding one or more pressure sensors (of correspondingly different total pressure ranges) can substantially improve the estimated measurement accuracy. In use, the subsystem would automatically switch to the most advantages pressure sensor. Another means for improvement is shown in Figures 8 and 11 wherein the quantity of water added to form the slurry was reduced. Sensing of a small sample condition could be accomplished by the user per se or perhaps by monitoring slinger rpm or power input or phase separator power input.

4.0 CONCLUSION

Although the most accurate of those considered, use of the USCS precision accumulator approach was rejected due to the potential of clogging the accumulator and control valving when metering a fecal or vomitus slurry. Integrating flow sensors do not appear to be adequate for the ABSS application unless accuracy can be materially improved. Fortunately, use of the phase separator as a centrifuge for mass measurement appears to result in reasonable accuracy. Equally important, the necessary equipments are currently state of the art (and less complicated) and clogging (at least with the Setra-Systems sensor) is not a problem.

TABLE 1

SOLIDS SUBSYSTEM MASS MEASUREMENT

BAG TYPE SUBSYSTEM

- COLLECT TOTAL QUANTITY
  ALL TYPES FECES AND VOMITUS
- MASS MEASUREMENT USING SMMD
  EXTERNAL TO SOLIDS SUBSYSTEM
- HANDLING PROBLEM
  OFFENSIVE SOLIDS/LIQUIDS IN PERMEABLE CONTAINER
- DIFFICULT TO REMOVE REAL TIME SAMPLES
- MINIMAL AUTOMATION OF TOTAL PROCESS

DRY-JOHN TYPE SUBSYSTEM

- COLLECT TOTAL QUANTITY
  ALL TYPES FECES AND VOMITUS
- ALL TYPE SAMPLES ACCOMMODATED
  % OF TOTAL ONLY
  CHEMICAL SAMPLE SMALL
- MASS MEASUREMENT
  INTEGRATED CHANGE IN SLINGER POWER/RPM
  REPEATABILITY QUESTIONABLE/NEED DATA
- MAXIMAL AUTOMATION OF TOTAL PROCESS POSSIBLE

HYDRO-JOHN TYPE SUBSYSTEM

- COLLECT TOTAL QUANTITY
  ALL TYPES FECES AND VOMITUS
- ALL TYPE SAMPLES ACCOMMODATED
  REAL TIME % OF TOTAL
  CHEMICAL SAMPLE REASONABLY LARGE
- LIQUIFY TO SLURRY CONDITION
  ADD KNOWN QUANTITY OF WATER (200 ML)
- MASS MEASUREMENT
  INTEGRATING FLOWSENSOR - GEOSCIENCE, LTD.
  POSITIVE DISPLACEMENT - GE USCS
  CENTRIFUGE - GE PHASE SEPARATOR
- MAXIMAL AUTOMATION OF TOTAL PROCESS POSSIBLE

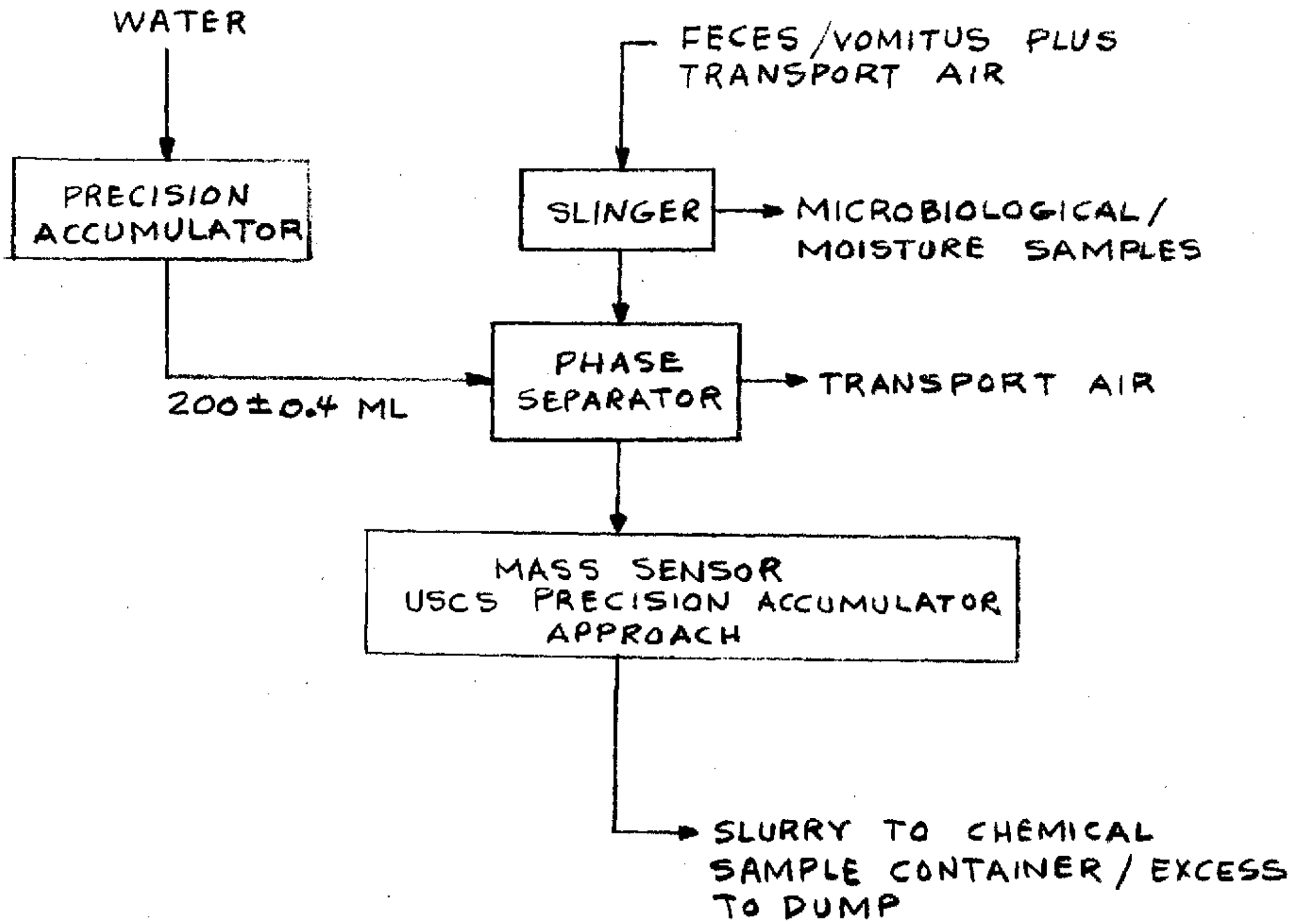
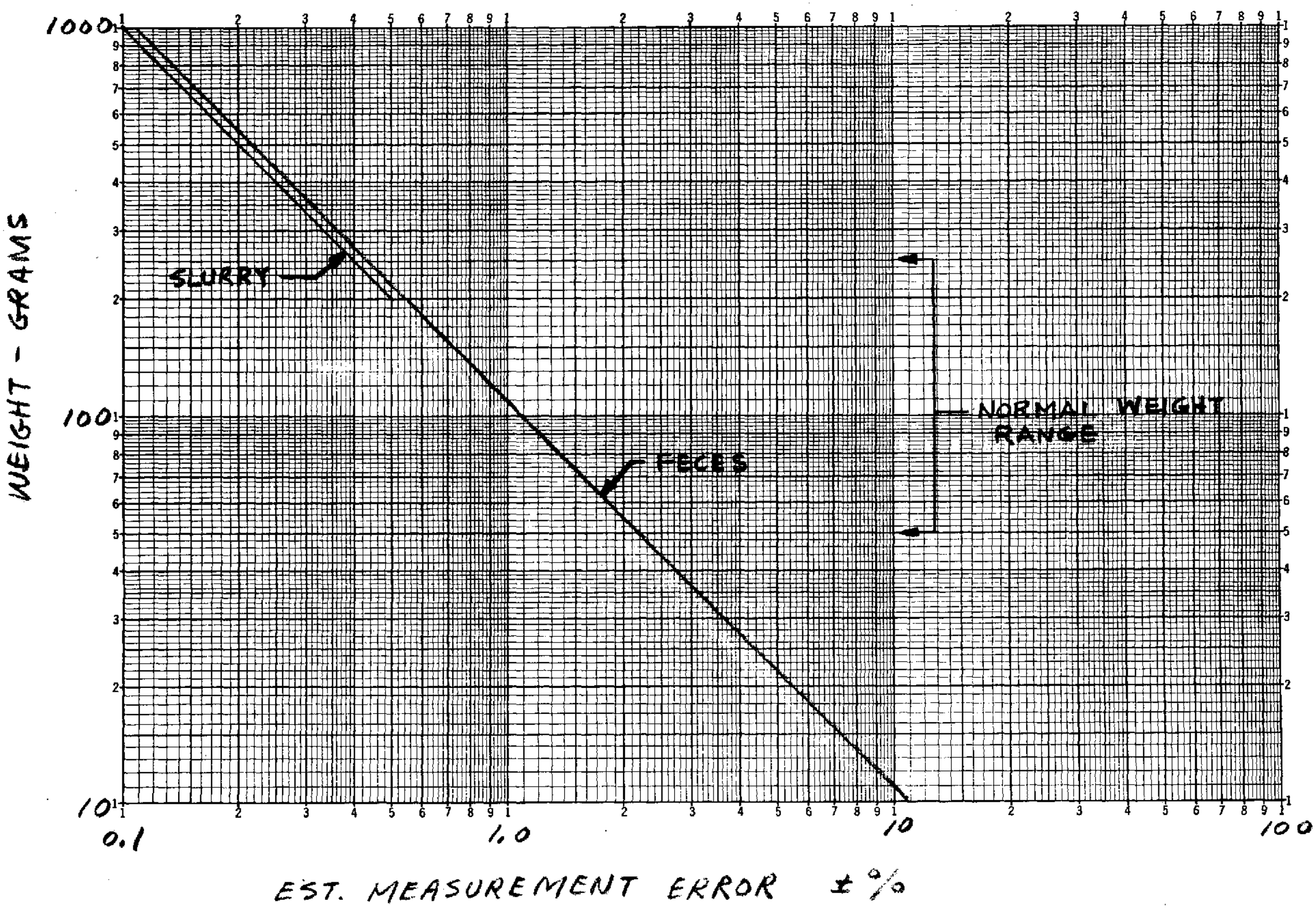


FIGURE 1 – SOLIDS SUBSYSTEM BLOCK DIAGRAM (PARTIAL)

FIGURE 2 - SOLIDS SUBSYSTEM - MASS MEASUREMENT USING USCS ACCUMULATOR



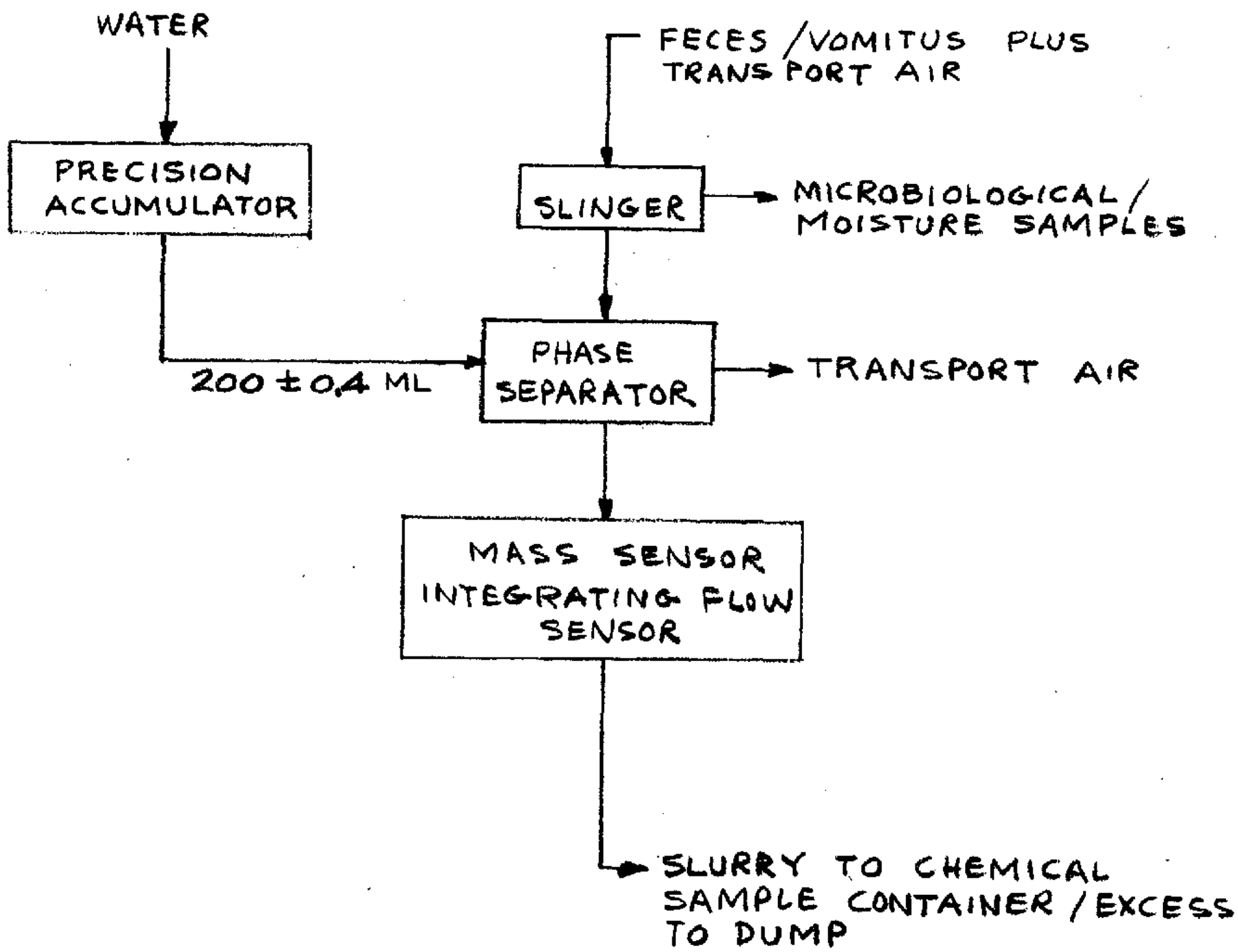


FIGURE 3 - SOLIDS SUBSYSTEM BLOCK DIAGRAM (PARTIAL)

FIGURE 4 - SOLIDS SUBSYSTEM - MASS MEASUREMENT*

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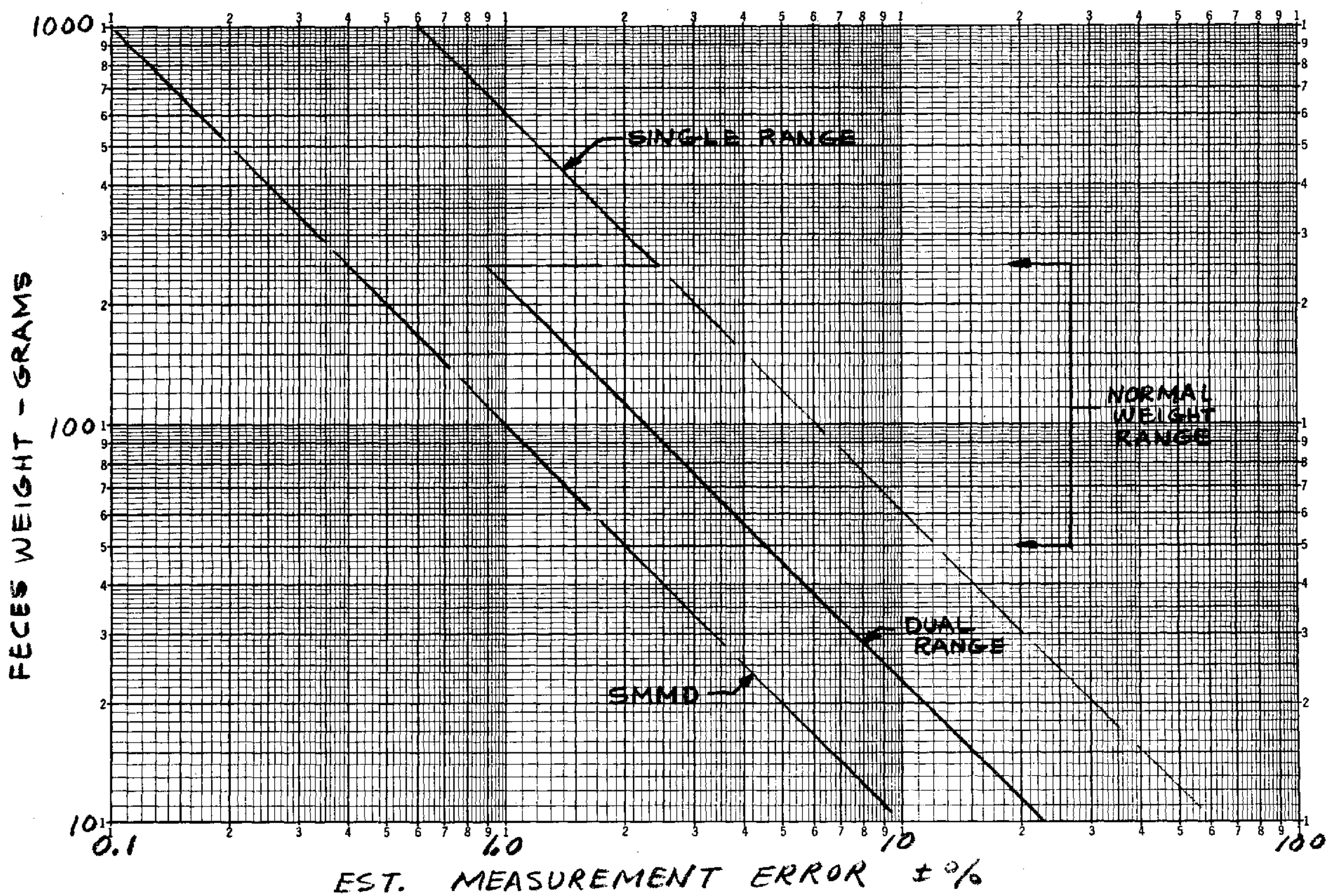
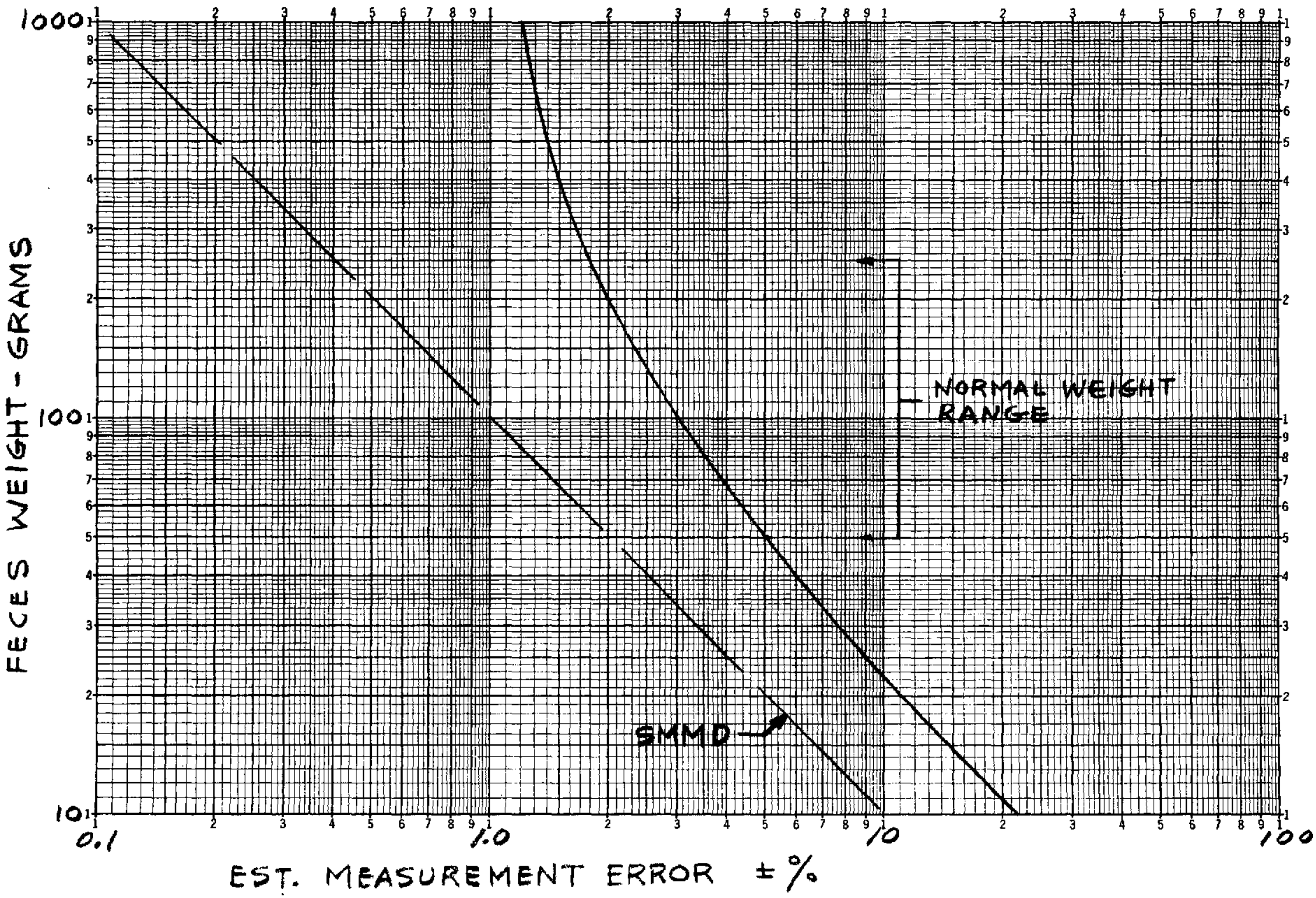


* INTEGRATING FLOW SENSOR - ACCURACY ± 0.5 % FS.

FIGURE 5 - SOLIDS SUBSYSTEM - MASS MEASUREMENT*



* ±1% GEOSCIENCE, LTD. THERMAL FLOW SENSOR

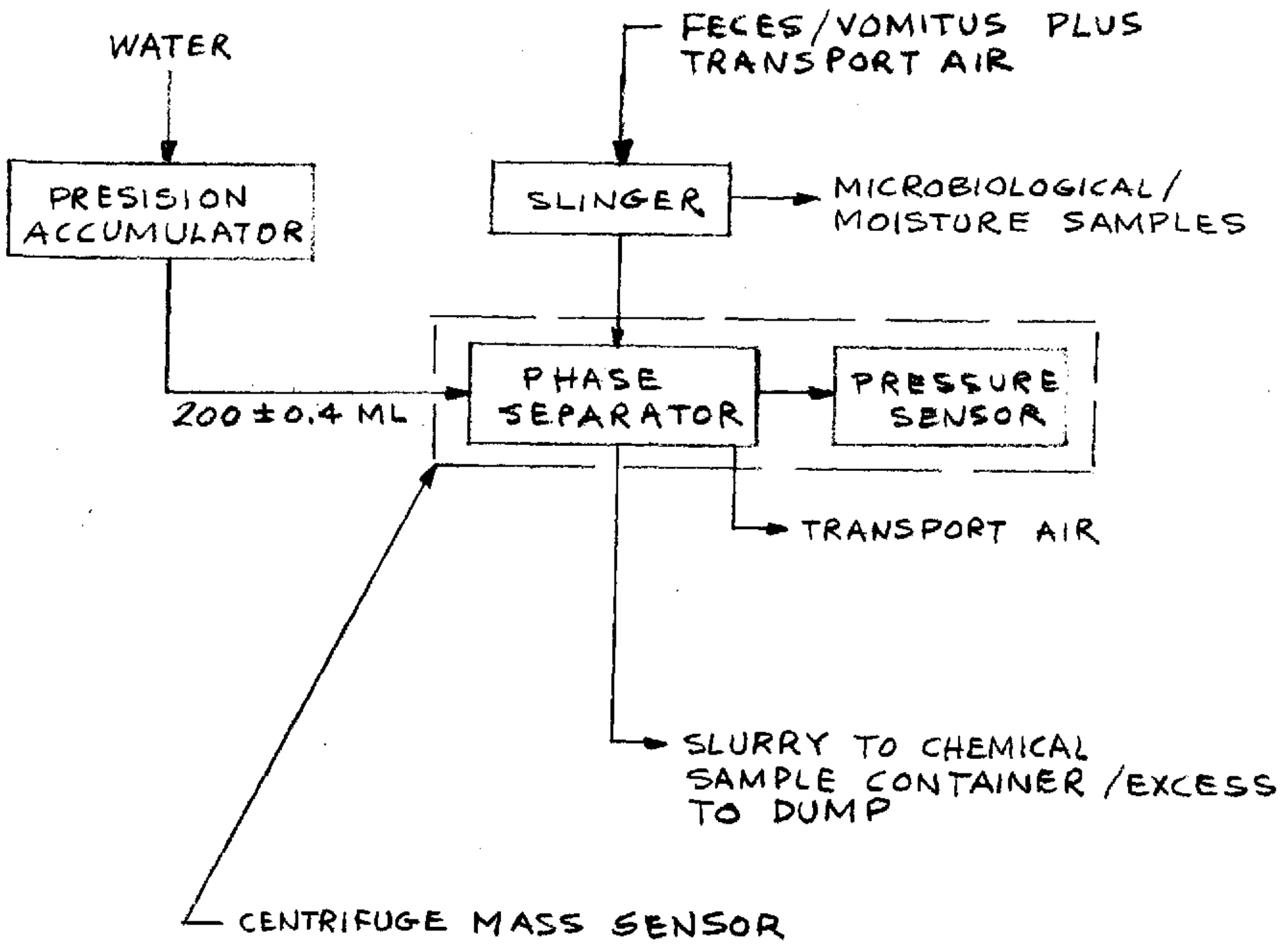
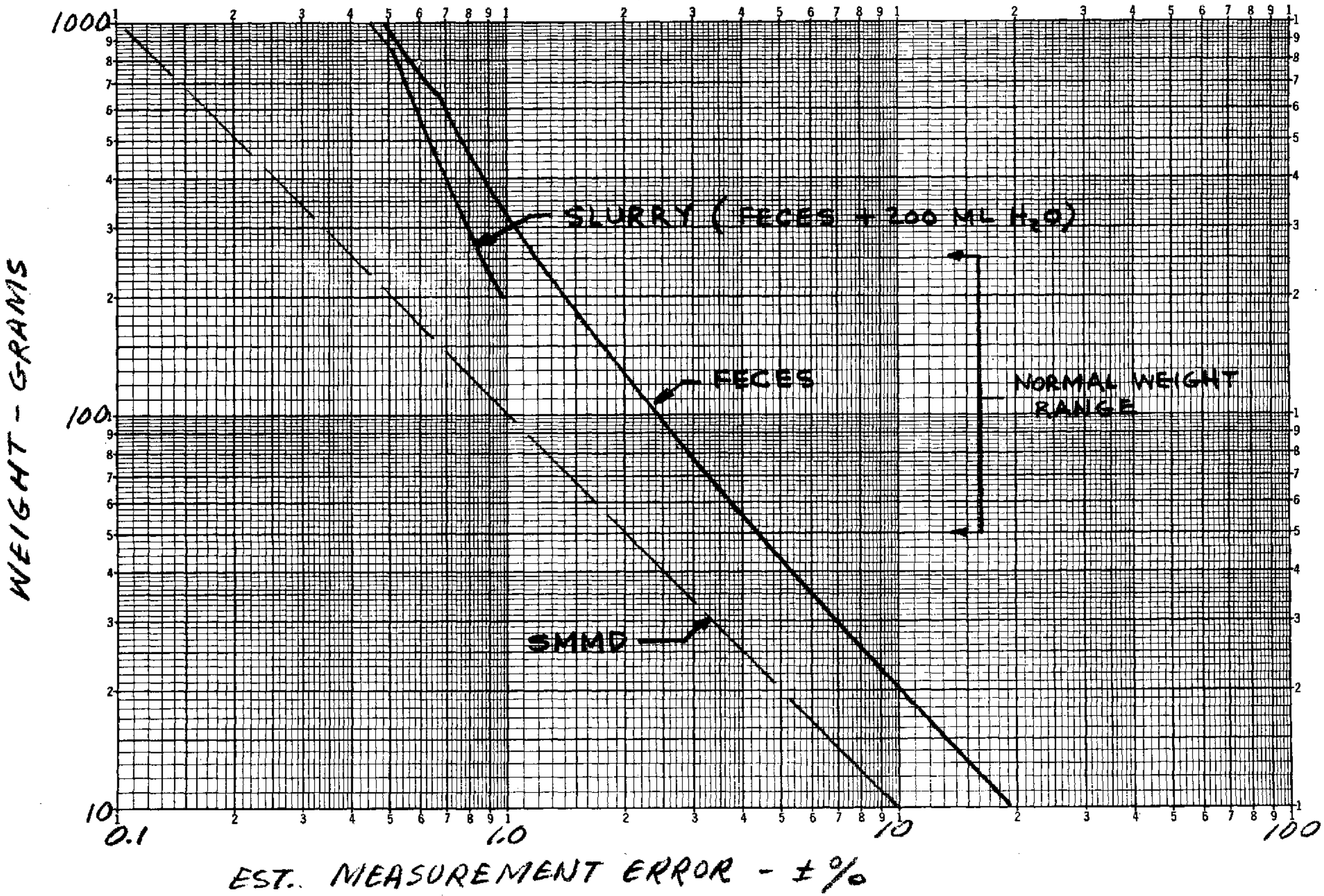


FIGURE 6 - SOLIDS SUBSYSTEM BLOCK DIAGRAM (PARTIAL)

FIGURE 7 - SOLIDS SUBSYSTEM - MASS SENSING*



* CENTRIFUGE - SINGLE RANGE SENSOR

FIGURE 8 – SOLIDS SUBSYSTEM – MASS SENSING*

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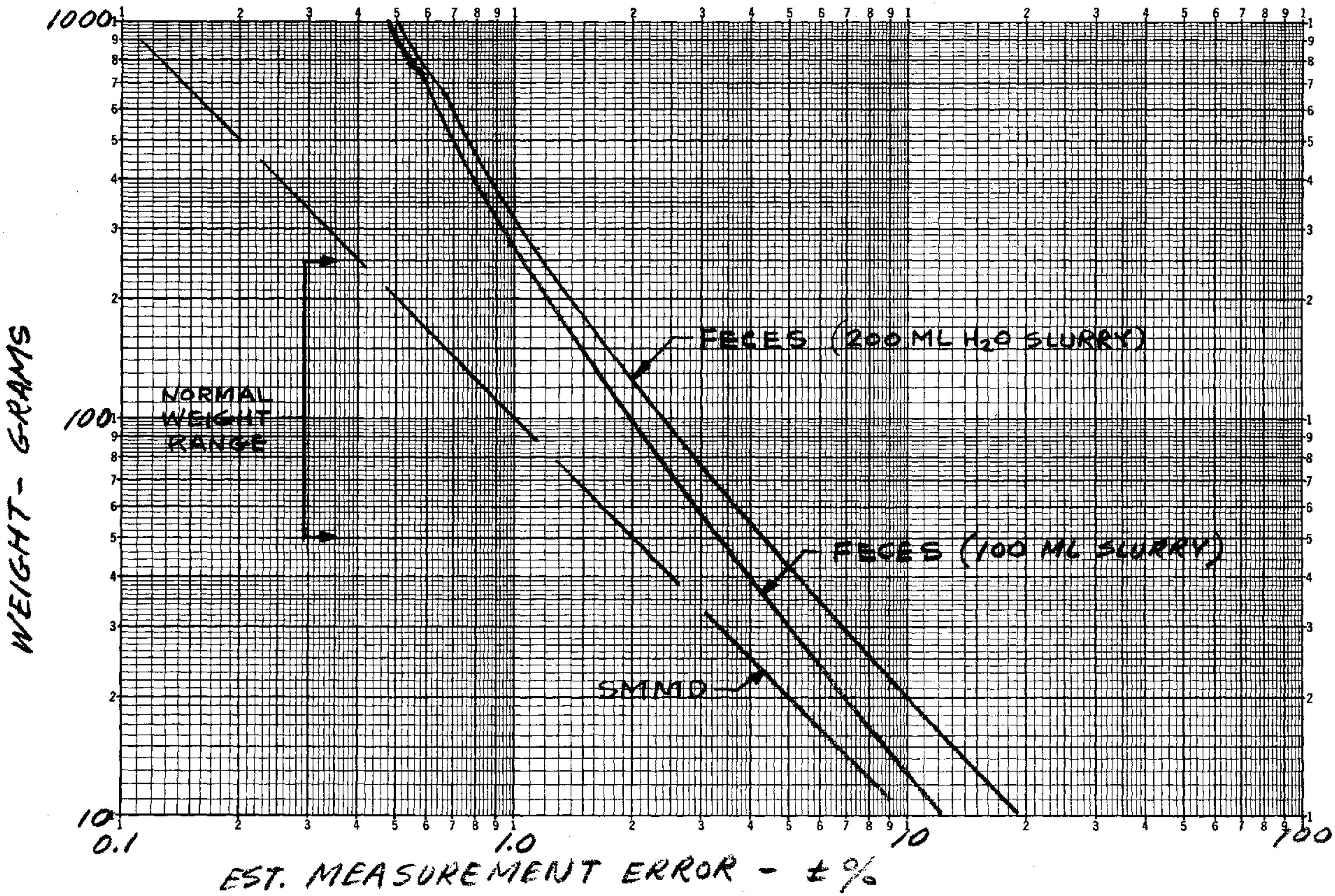
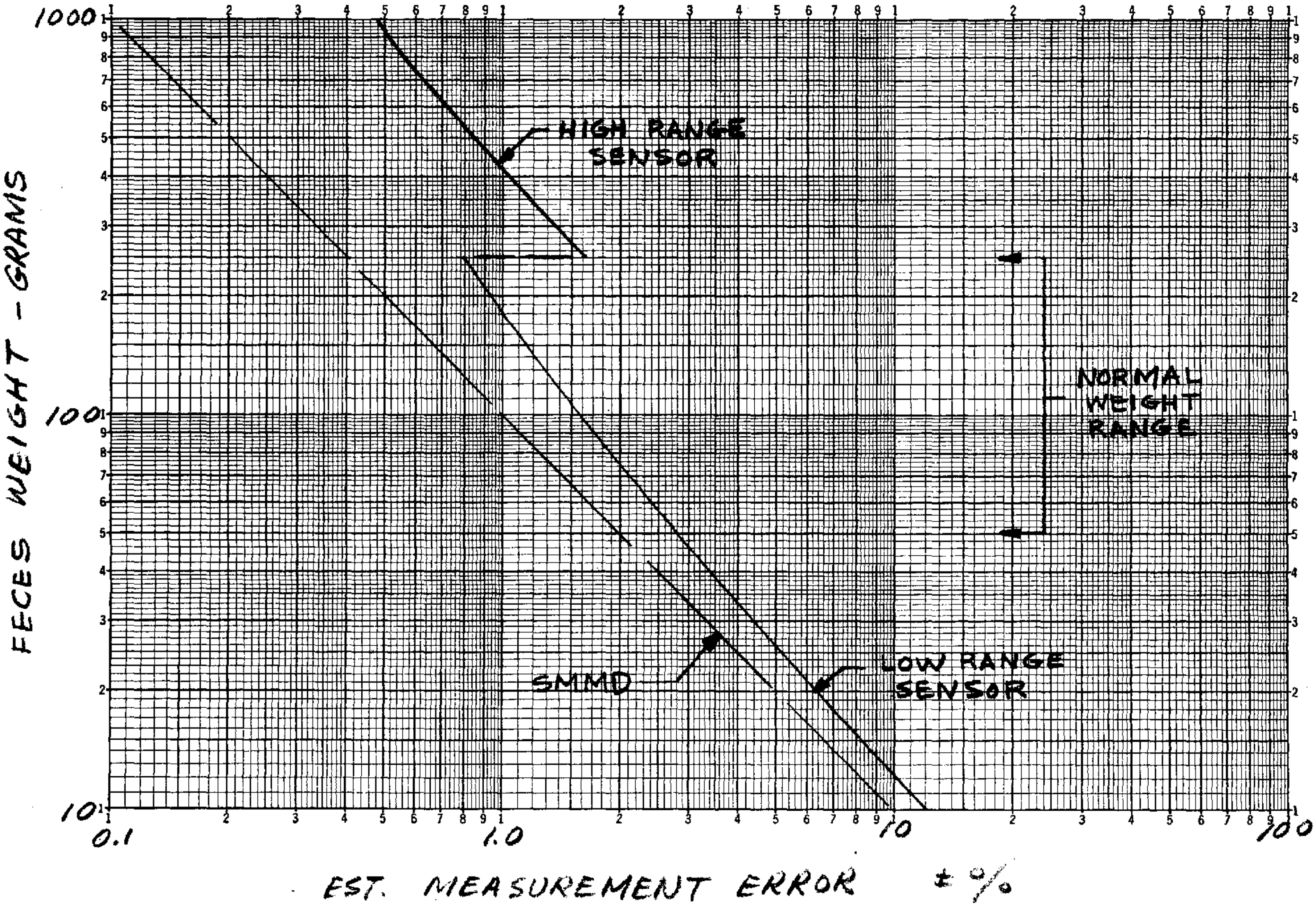


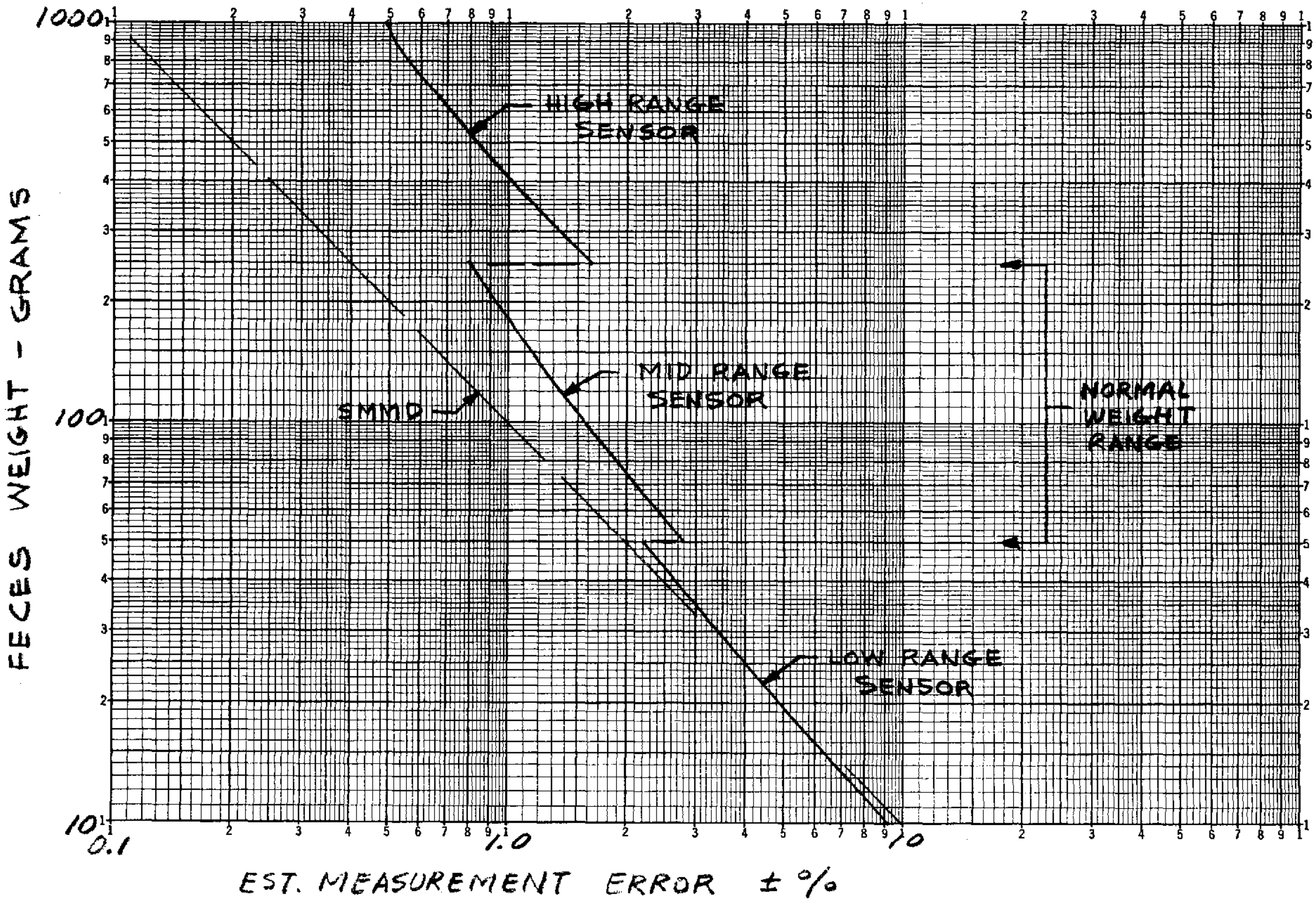
* CENTRIFUGE – SINGLE RANGE SENSOR

FIGURE 9 – SOLIDS SUBSYSTEM – MASS MEASUREMENT*



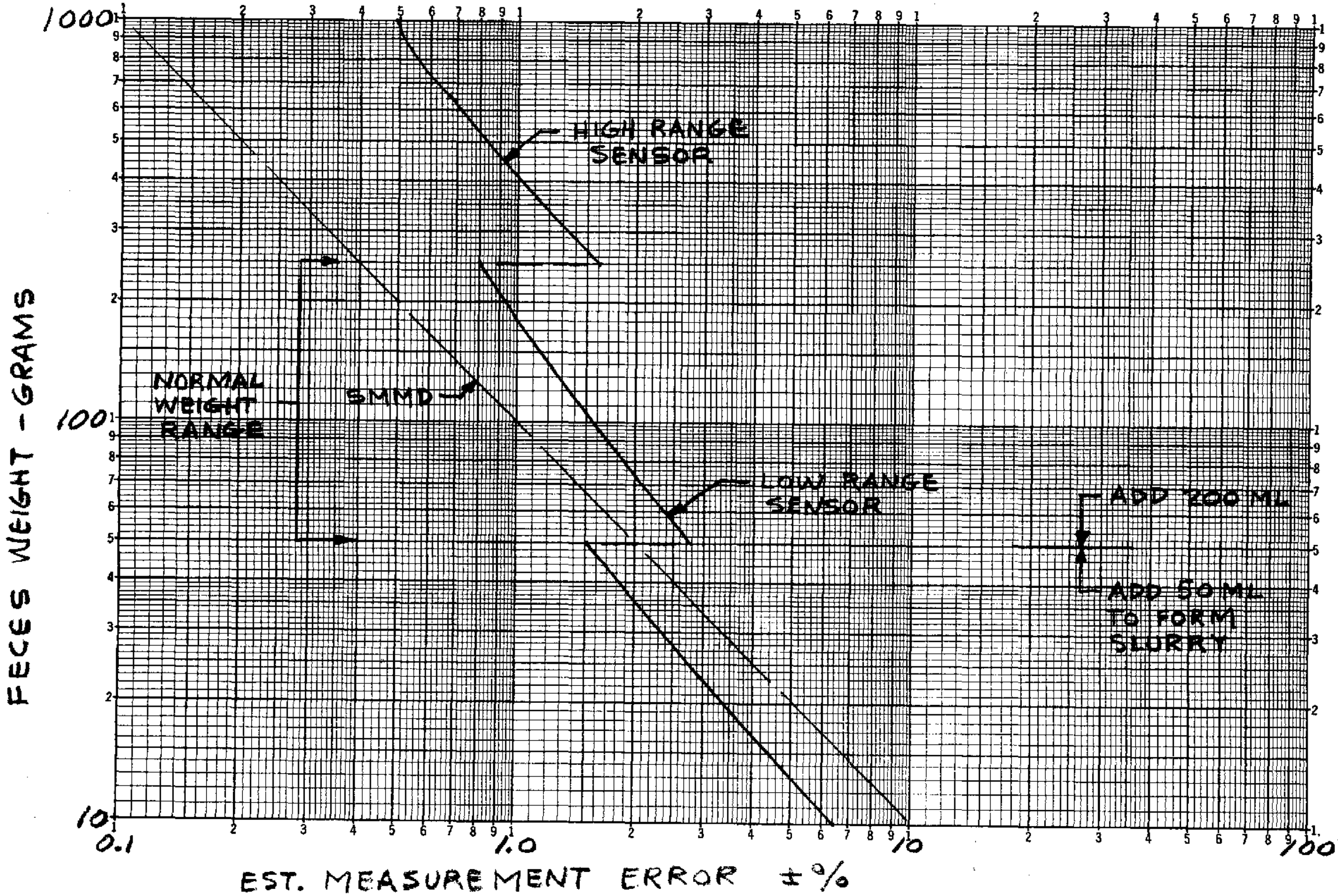
* CENTRIFUGE – DUAL RANGE SENSING

FIGURE 10 - SOLIDS SUBSYSTEM - MASS MEASUREMENT *



* CENTRIFUGE - TRI RANGE SENSING

FIGURE 11 – SOLIDS SUBSYSTEM – MASS MEASUREMENT *



* CENTRIFUGE – DUAL RANGE PLUS SMALL SAMPLE MODE

ENCLOSURE A – TYPICAL CALCULATION

CONCEPT : SINGLE RANGE SENSOR (REF. FIGURE 8)

STEP 1 : DETERMINE CENTRIFUGE RPM FOR 0.5 PSI PRESSURE SENSOR OUTPUT AT 1200 ML FLUID LEVEL

$$p = \frac{\rho}{g}\frac{\omega^2}{2}\left(r_0^2 - r^2\right) \tag{1}$$

WHERE

p = FLUID STATIC PRESSURE (FOR ZERO GRAVITY CONDITIONS) AT r_0.

ρ = .0362 LBS/IN^3 (DENSITY OF H_2O)

g = 386 IN/SEC^2

r_0 = 4.2 IN.

r = VORTEX RADIUS AT 1200 ML LEVEL
= 2.87 IN (SEE FIGURE A1)

ω = CENTRIFUGE RPM IN RAD/SEC.

THEN FROM EQUATION (1),

$$\omega^2 = \frac{2(0.5)386}{.0362\,(4.2^2 - 2.87^2)}$$

$$\omega = 33.8 \text{ RAD/SEC.}$$

STEP 2 : EST. PRESSURE CHANGE DUE TO VARIATIONS IN CENTRIFUGE RPM

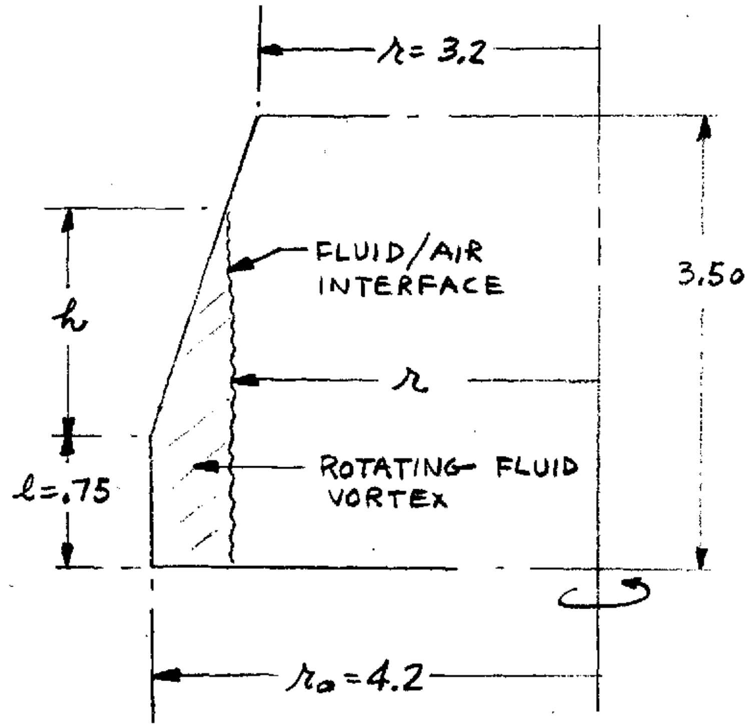
FROM EQ. (1),

$$p + \Delta p = k\,(\omega + \Delta\omega)^2$$

$$p + \Delta p = k\,(\omega^2 + 2\omega\Delta\omega + \Delta\omega^2)$$

NEGLECTING $\Delta\omega^2$ AND SUB. FOR k FROM EQ. (1),

$$\Delta p = \frac{\rho}{g}\left(r_0^2 - r^2\right)\omega\,\Delta\omega \tag{2}$$



PHASE SEPARATOR CONFIGURATION

VOLUME OF FLUID IN VORTEX

$$V = \pi \left[r_o^2 l + \frac{h}{4} \left\{ (r_o + r)^2 + \frac{(r_o - r)^2}{3} \right\} - r^2 (h + l) \right]$$

r	h	VOLUME
2.87 IN.	2.75 IN.	1200 ML
3.05	2.75	1000
3.2	2.75	847
3.5	2.0	467
3.6	1.7	377
3.7	1.4	283
3.8	1.1	211
3.9	0.8	144

FIGURE A1 - PHASE SEPARATOR VOLUME/DIMENSION RELATIONSHIPS

WHERE

$\Delta\omega$ = VARIATION IN CENTRIFUGE RPM

BASED ON PRESENTLY AVAILABLE EQUIPMENT, A REASONABLE VALUE FOR $\Delta\omega = \pm 0.1\%$.

$$\Delta\omega = .001(33.8) = 0.0338 \text{ RAD/SEC.}$$

STEP 3: EST. MIN. PRESSURE CHANGE DETECTION FOR PRESSURE SENSOR

FOR SETRA-SYSTEMS MODEL 237, REPEATABILITY IS ± 10 mv OVER OUTPUT RANGE OF 5000 mv.

$$\text{SENSOR ERROR} = \frac{0.5(10)}{5000} = \pm .001 \text{ PSI}$$

STEP 4: DETERMINE CENTRIFUGE ERROR FROM EQ.(2) AT VARIOUS FLUID LEVELS IN CENTRIFUGE. THUS FOR 1000 ML,

$$\Delta p = \frac{.0362}{386}(4.2^2 - 3.05^2)\,33.8(.0338) = .00089 \text{ PSI}$$

STEP 5: DETERMINE RMS ERROR DUE TO SENSOR AND CENTRIFUGE. THUS FROM STEPS 3 AND 4,

$$\Delta p' = \text{RMS ERROR} = \sqrt{.001^2 + .00089^2} = \pm .00144 \text{ PSI}$$

STEP 6: DETERMINE CHANGE IN FLUID LEVEL RADIUS TO PRODUCE $\Delta p'$.

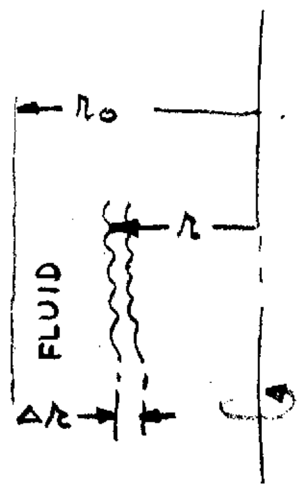
FROM EQ. (1),

$$p + \Delta p' = k\left[r_0^2 - (r - \Delta r)^2\right]$$

$$p + \Delta p' = k(r_0^2 - r^2 + 2r\Delta r + \Delta r^2)$$

NEGLECTING Δr^2

$$\Delta p' = k\,2r\Delta r = \frac{\rho}{g}\omega^2 r\Delta r$$



AND

$$\Delta r = \frac{g}{\rho}\,\frac{\Delta k'}{\omega^2 r}$$

USING $\Delta k'$ FROM STEP 5,

$$\Delta r = \frac{386}{.0362}\,\frac{(.00144)}{33.8^2\,(3.05)} = .00412 \text{ IN.}$$

STEP 7: DETERMINE MASS OF VOLUME CHANGE EQUIVALENT TO Δr

$$\Delta W = 2\pi r \Delta r \rho (h + l)$$

$$= 2\pi (3.05) .00412 (.0362) (2.75 + .75)$$

$$= .00995 \text{ LBS.}$$

$$= 4.51 \text{ GRAMS}$$

STEP 8: DETERMINE OVERALL ERROR BY COMBINING WITH THE 200 ML WATER INPUT ERROR OF ± 0.4 GMS.

$$\text{OVERALL ERROR} = \sqrt{4.51^2 + 0.4^2} = \pm 4.51 \text{ GMS.}$$

AND

$$\text{SLURRY MEASUREMENT ERROR} = \frac{4.51}{1000} \times 100 = \pm .45\,\%$$

BUT

$$\text{SAMPLE MEASUREMENT ERROR} = \frac{4.51 \times 100}{(1000 - 200)} = \pm .56\,\%$$

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DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
4-19-73		ABSS - Solids Subsystem	

SUBJECT

MICROBIOLOGICAL CONSIDERATIONS

INFORMATION REQUESTED/RELEASED

1.0 SUMMARY

On a relative advantage basis, either air or vacuum drying is the preferred method of feces microorganism control. Since for some missions, overboard dump of vapor and gases may be prohibited, the air drying approach is recommended for the ABSS Solids Subsystem. A nominal 10 cfm blower capability, controlled by a humidity level sensor, is required.

2.0 MICROORGANISM CONTROL PROCESSES

2.1 General

Since the waste products(feces and vomitus)which the ABSS Solids Subsystem must be designed to handle are highly contaminated and can support the growth of the indigenous microbes, as well as other opportune contaminants, microbiological control must be exercised in the normal collection and storage of such products, as well as under emergency modes of operation. Proper storage of body wastes by a method which kills the microorganisms present or renders them incapable of further growth will prevent further odor and gas production and eliminate the health hazard. Such a consideration defines the general requirements from a microbiological point of view for the Solids Subsystem:

1. The subsystem must be capable of containment of all discharge whether gaseous, liquid or solid.

2. The subsystem must be capable of high reliability for inactivating or inhibiting the growth of the microbial populations during storage.

3. Externally, the subsystem must be capable of being maintained in a sanitary condition.

The following discussion summarizes the microbiological aspects of the methods by which the waste (fecal waste and/or vomitus) can be treated for safe storage. The discussion provides the basis for the tradeoffs and choices for waste treatment. In general, the methods considered for microbiological control are heat (wet or dry), desiccation and chemical disinfection.

cc: G. L. Fogal (4)
J. K. Mangialardi
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2.2 Wet/Dry Heat

Wastes may be pasteurized, sterilized, or the microbial growth inhibited, by heat depending upon the degree and type of heat applied. Almost any heat stabilization process must be complemented with aseptic storage after treatment.

Heat applied either internally or externally (to generate steam internally) or by admission of steam into essentially a pressure vessel, can result in sterilization (at temperatures of 105-120°C) of the waste and hence the waste rendered microbially stable. Such a concept has obvious engineering and operational complications which must be taken into account in the overall subsystem design. This process, which is analogous to steam cooking or autoclaving, has been shown to be microbiologically effective and feasible in studies on various engineering prototype systems. The waste, although stabilized, must be maintained in an aseptic condition because if re-contaminated it is capable of supporting the growth of organisms (unless such a process is followed by drying). Deactivation may be accomplished at somewhat lower temperatures (60 to 70°C).

2.3 Desiccation

Desiccation by any technique (freeze-drying, air-drying with or without auxiliary heat, vacuum drying and chemical desiccation) can render the microbial flora of waste material stable due to the inhibition of their metabolic activity. Although it is reasonable to expect that some degradation in the viable microbial population will occur due to die-off, desiccation cannot be relied upon to kill all microorganisms. The requirement for maintenance of aseptic storage conditions also exists with this approach. Generally speaking, if the amount of water in the waste is reduced to less than 50 percent (and preferably more like 5-10 percent) of the original water content, the microbial population should not pose a problem.

2.4 Chemical Disinfection

Germicidal chemicals for the stabilization of stored wastes can be used as gases, liquids, or solids. Each of these has certain attendant advantages and disadvantages. The use of gaseous agents may be summarily dismissed because the typical candidates are all toxic, or combustible and release of these agents to the spacecraft atmosphere could be catastrophic.

Liquid compounds or solutions of solid germicides are very effective for stabilization of all wastes, but are particularly effective if a wet stage is involved. Control throughout the treatment and storage period requires no precautions other than reliable containment.

Solid or powdered germicides are suitable for use on wet wastes only (or those passing through a wet stage) as they must dissolve in water contained in the waste before they become effective. Such germicides are normally quite soluble. Feces contain more than enough natural water to facilitate dissolution of solid germicidal agents. Intimate mixing of the germicide with fecal material will, however, be required to obtain the contact necessary for rapid efficient action (for a minimum quantity of germicide).

Liquid germicides appear to offer more inherent advantages. Minimum volume and weight, automated dispensing, and the most reliable waste stabilization available for short and medium length missions are the major general characteristics displayed. Microorganisms are killed and the waste rendered incapable of supporting further growth of even opportune contaminants in the cabin air. Consequently, there is no problem of recontamination, spreading of disease organisms, or secondary gas and odor production.

The selection of suitable germicides is complicated by the fact that the disinfection of massive quantities of organic matter involves unusual problems. In concentrated wastes, organisms are distributed through a masssive quantity of organic matter that "ties up" or inactivates most germicides. Therefore, acceptable germicides are those that are effective at low concentrations and are not greatly inactivated by organic matter. Furthermore, the germicide should be capable of killing the widest spectrum of microorganisms, since fecal waste may contain an infinite variety of microbial species. Of the hundreds of preparations tested by various groups working on waste stabilization techniques, those identified in Table 2-1 have proved effective for the stabilization of feces. Of these, Betadyne (povidone iodine) is considered the best choice in that possible inhalation or injection by the spacecraft crew is not harmful.

TABLE 2-1. CANDIDATE GERMICIDES FOR FECES STABILIZATION

NAME	APPROXIMATE CONCENTRATION (% OF WEIGHT OF SAMPLE)	FORM OF APPLICATION
<u>Feces</u>		
Sodium Orthophenolphenolate Sodium Chlorophenolphenolates	3-5	Liquid or Solid
Neomycin Sulfate Plus Myrislyl Gamma Picolinium Chloride	1-5	Liquid or Solid
8-Guinolinol Sulfate	3-5	Liquid
Iodine (Iodophor/Povidone)	4	Liquid or Solid

2.5 Other

Other waste stabilization methods which have been considered in the past for their disinfection or sterilization capability but which appear to have little potential application to the Solids subsystem include refrigeration, filtration, radiation and aerobic and anaerobic digestion.

3.0 MICROORGANISM CONTROL IMPLEMENTATION

Each of the following approaches are considered within the constraints of applicability to the basic DRY-JOHN type collection hardware planned for the Solids Subsystem. Thus each method of microorganism control was considered in the context of a solids waste storage container with an integral, internal slinger device to spread the waste solids in a relatively thin, uniform layer over the inner periphery of the storage container.

3.1 Desiccation

3.1.1 Vacuum Drying

Desiccation by vacuum drying, actually freezing due to rapid moisture evaporation followed by sublimation, is readily accomplished using the basic GE DRY-JOHN configuration. Figure 3-1 illustrates the vacuum drying concept. After defecation is completed, the slide valve is closed by the user. This action deactivates the blower and slinger motors and opens valve S1 to vacuum. Valve S2 is a manual shut-off.

Figure 3-2 shows the time required to dry fecal samples within the solids storage container for two ambient air conditions. Figure 3-3 shows the comparative time to vacuum dry fecal samples without the benefit of slinger action.

3.1.2 Air Drying

In this concept, Figure 3-4, spacecraft ambient atmosphere is used to dry the feces. Closing the slide valve causes the air inlet valve S1 to open. The blower then circulates relatively dry spacecraft air thru the solids storage container and return to ambient via the bacteria and odor filters. This circulated air rapidly dries the thin feces layer by direct evaporation of the water content. The slinger is also operated to assist internal circulation (within the storage container) of the air flow.

Important variables are the use rate, the relative humidity of the ambient air, the air flow rate, and the percent water content which must be achieved in the dried feces (for bacteria deactivation). Figure 3-5 and 3-6 illustrate the results of laboratory tests using a GE DRY-JOHN prototype model in a test setup simulating the concept shown in Figure 3-4. Note that the air dry time is relatively independent of sample size and water content and air flow rate. Figure 3-7 shows the effect on drying time if the slinger is not used to distribute the feces within the storage container. Note that drying time is greatly increased.

Figure 3-8 shows the required minimum air flow through the storage container as a function of spacecraft ambient relative humidity. The figure assumes that the air leaving the storage container will be in a saturated condition. The data of Figure 3-5 indicates that saturated conditions were not achieved (as might be expected at the high air flow rates used). We may deduce, however, from the data of Figure 3-5 (See Figure 3-9) that saturated conditions, even at low air flow rates, will only occur

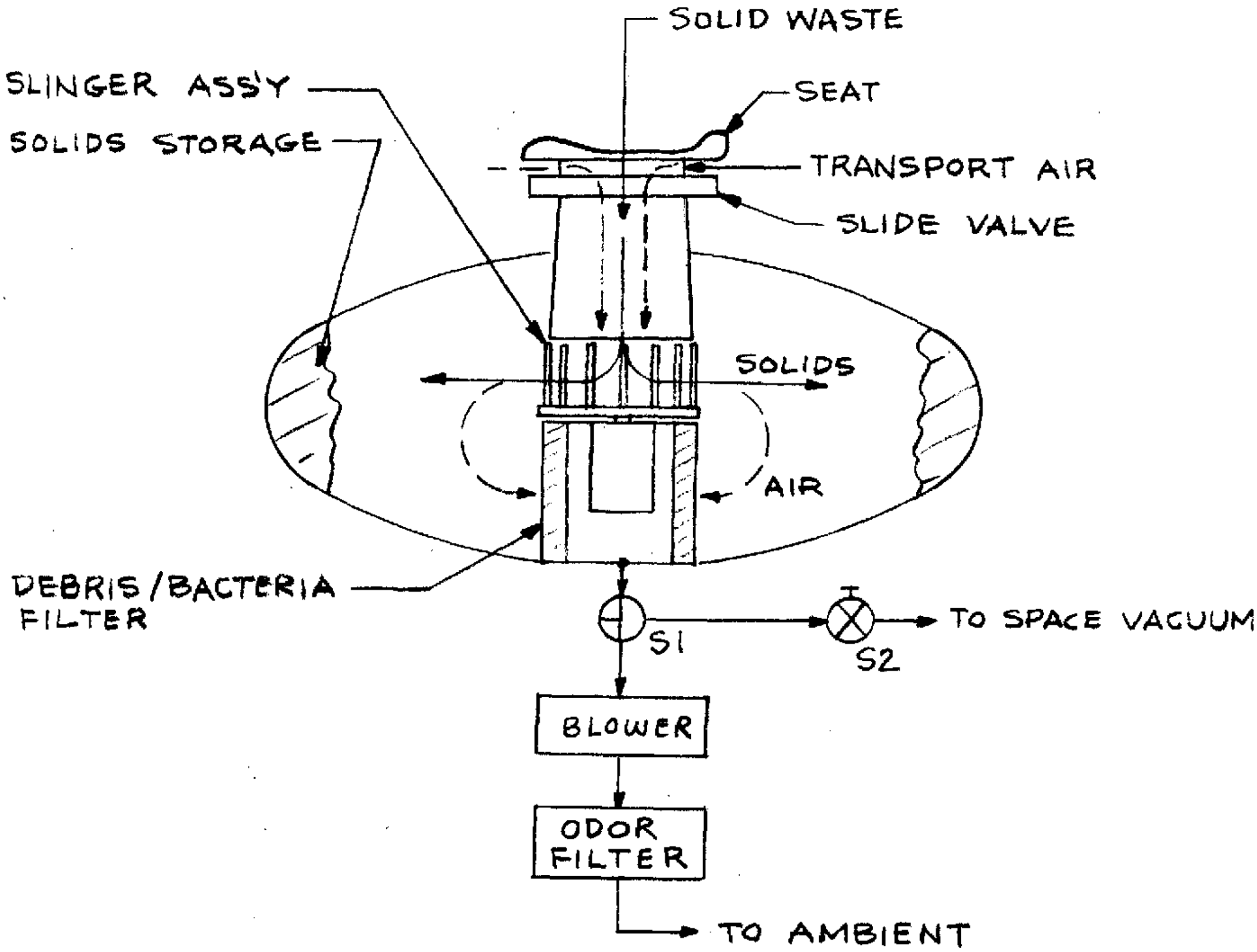


FIGURE 3-1 VACUUM DRYING CONCEPT

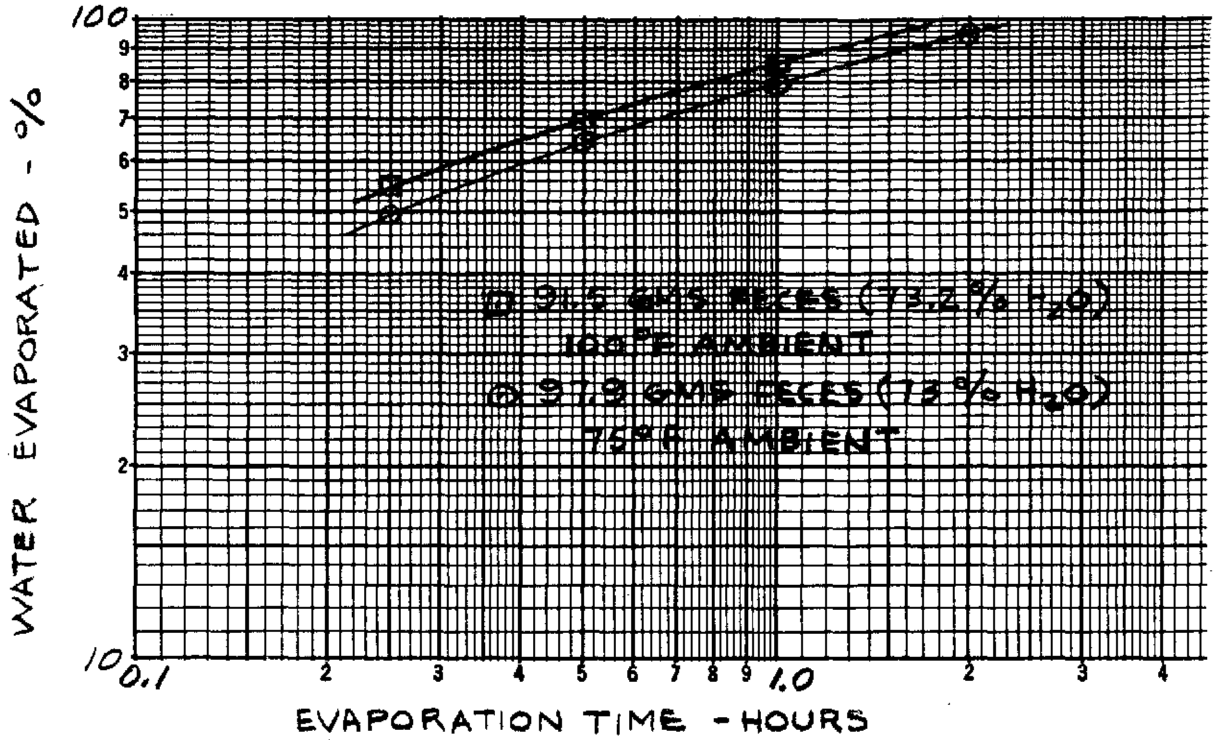


FIGURE 3-2 FECES VACUUM DRYING

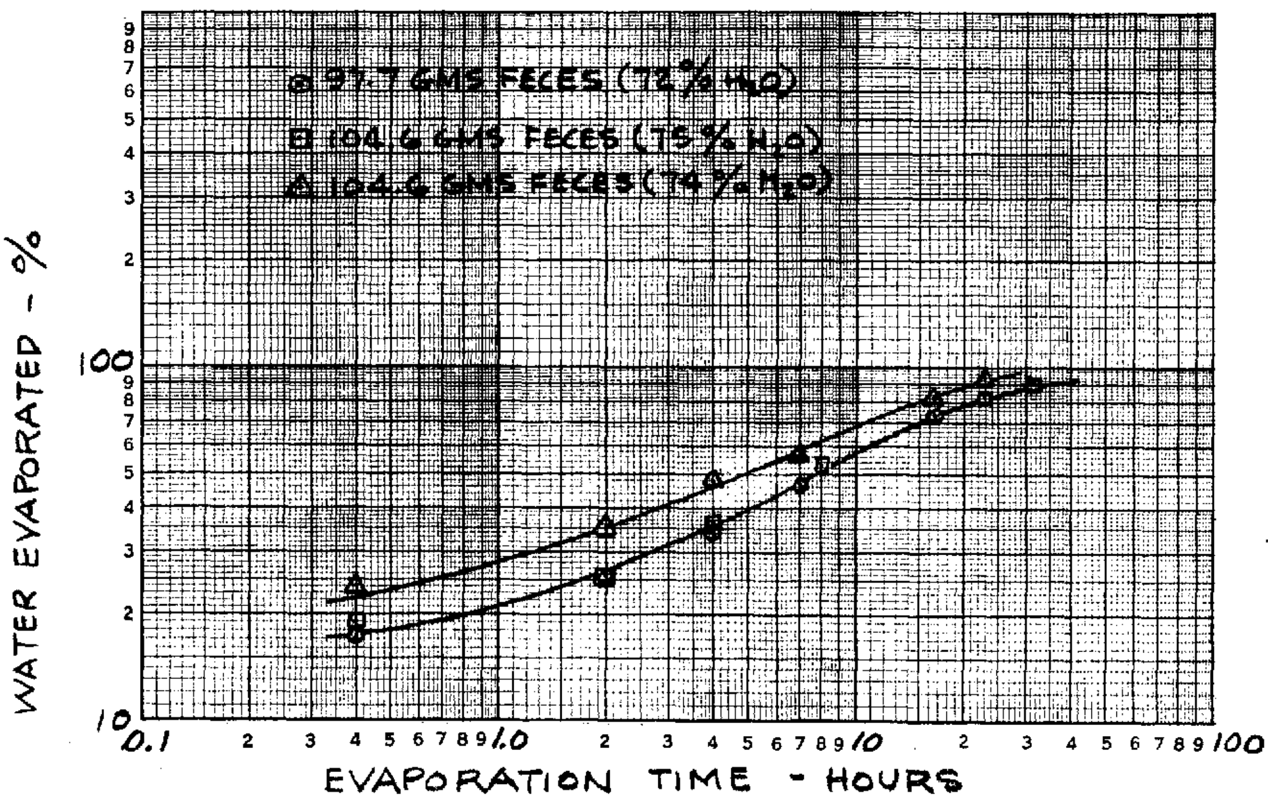


FIGURE 3-3 FECES VACUUM DRYING (WITHOUT DISTRIBUTION BY SLINGER)

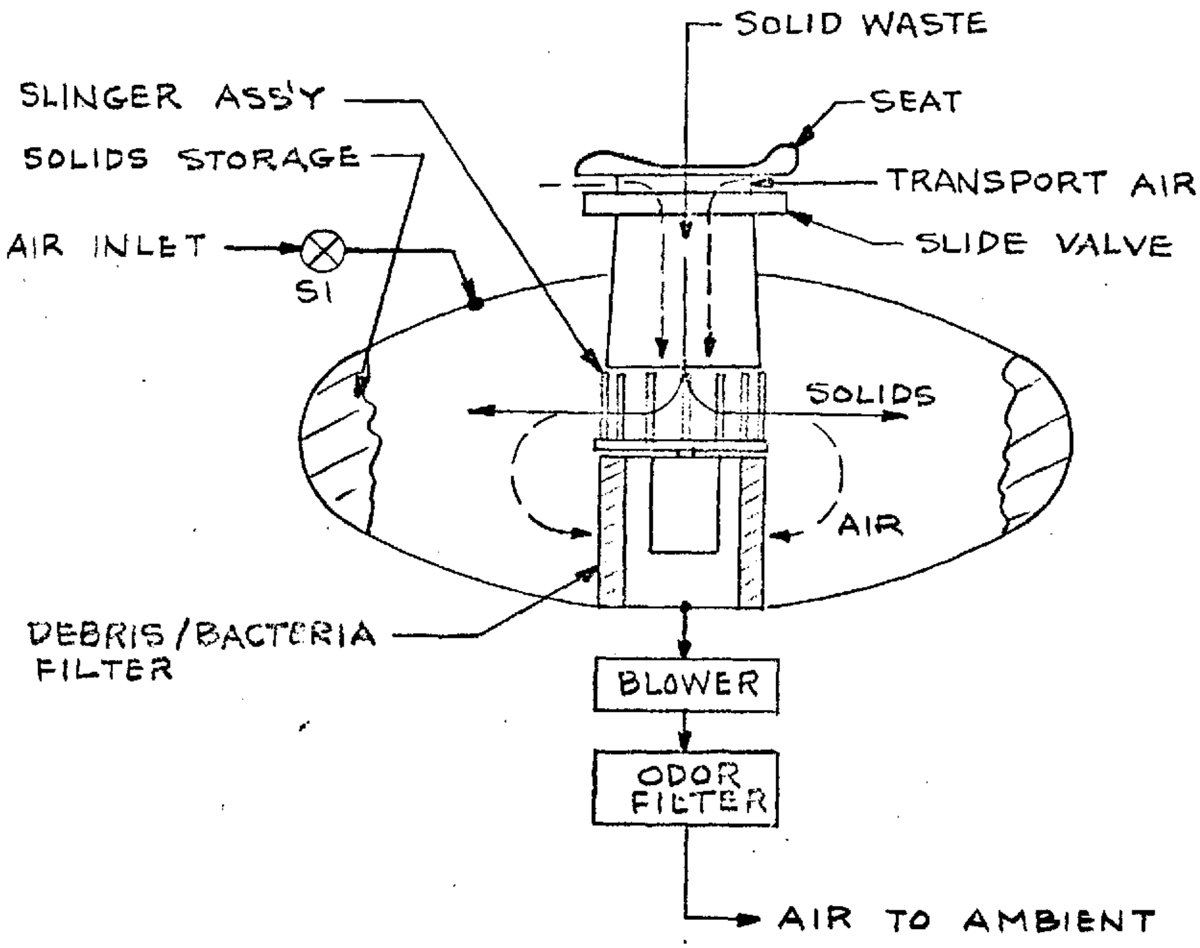
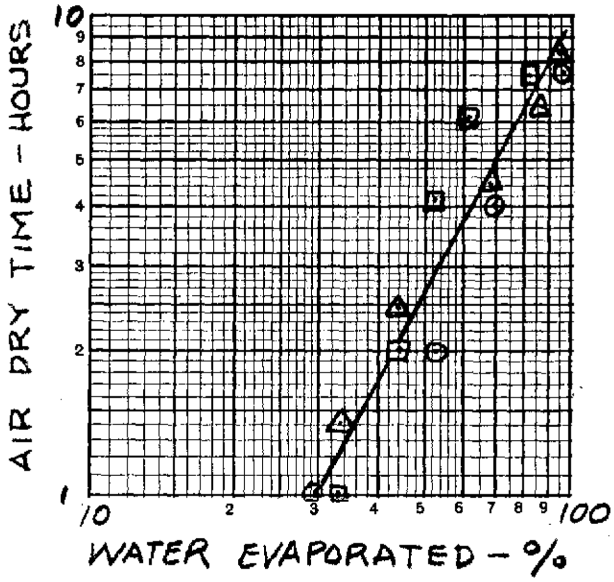


FIGURE 3-4 AIR DRYING CONCEPT

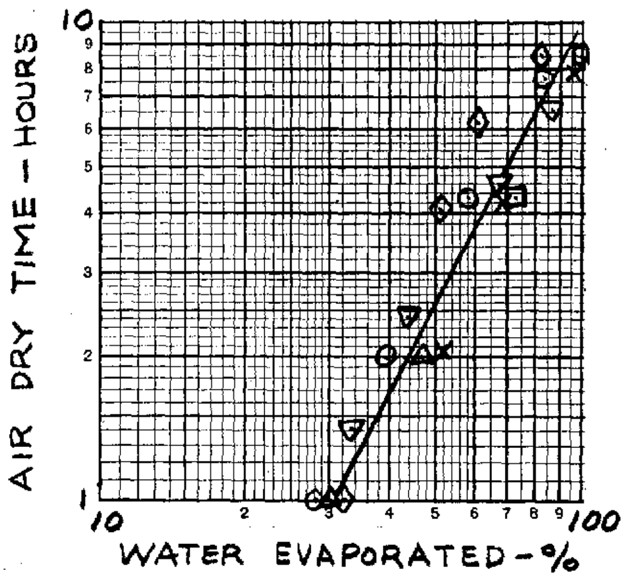


⊙ 100 GMS. FECES
72 % WATER CONTENT
2.5 CFM, 75°F, 35% RH

△ 100 GMS. FECES
64 % WATER CONTENT
5 CFM, 77°F, 36% RH

□ 100 GMS. FECES
81 % WATER CONTENT
10 CFM, 74°F, 36% RH

FIGURE 3-5 FECES AIR DRYING



⊙ 52.5 GMS. FECES
82.5 % WATER CONTENT
2.5 CFM, 74°F, 36% RH

× 100 GMS. FECES
72 % WATER CONTENT
2.5 CFM, 75°F, 35% RH

△ 169.5 GMS. FECES
78 % WATER CONTENT
5.0 CFM, 77°F, 37% RH

▽ 100 GMS. FECES
64 % WATER CONTENT
5.0 CFM, 74°F, 36% RH

□ 183.3 GMS. FECES
81 % WATER CONTENT
10 CFM, 78°F, 37% RH

◇ 100 GMS. FECES
81 % WATER CONTENT
10 CFM, 74°F, 36% RH

FIGURE 3-6 FECES AIR DRYING

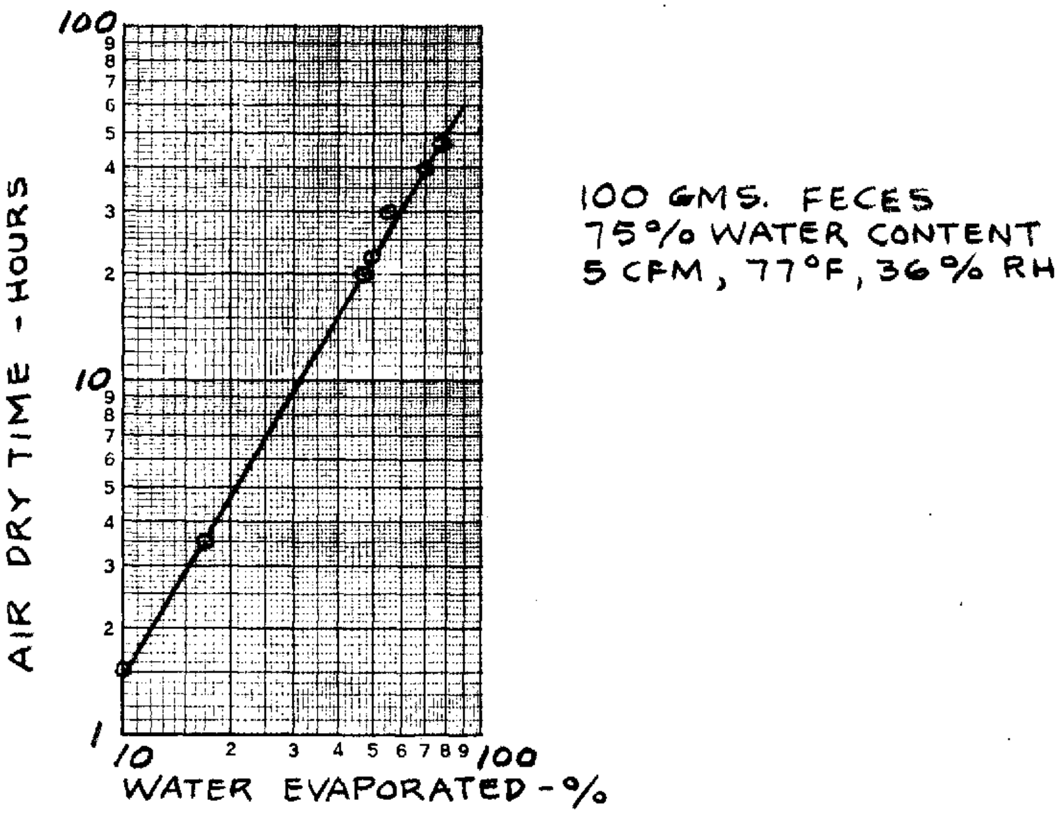


FIGURE 3-7 FECES AIR DRYING (WITHOUT DISTRIBUTION BY SLINGER)

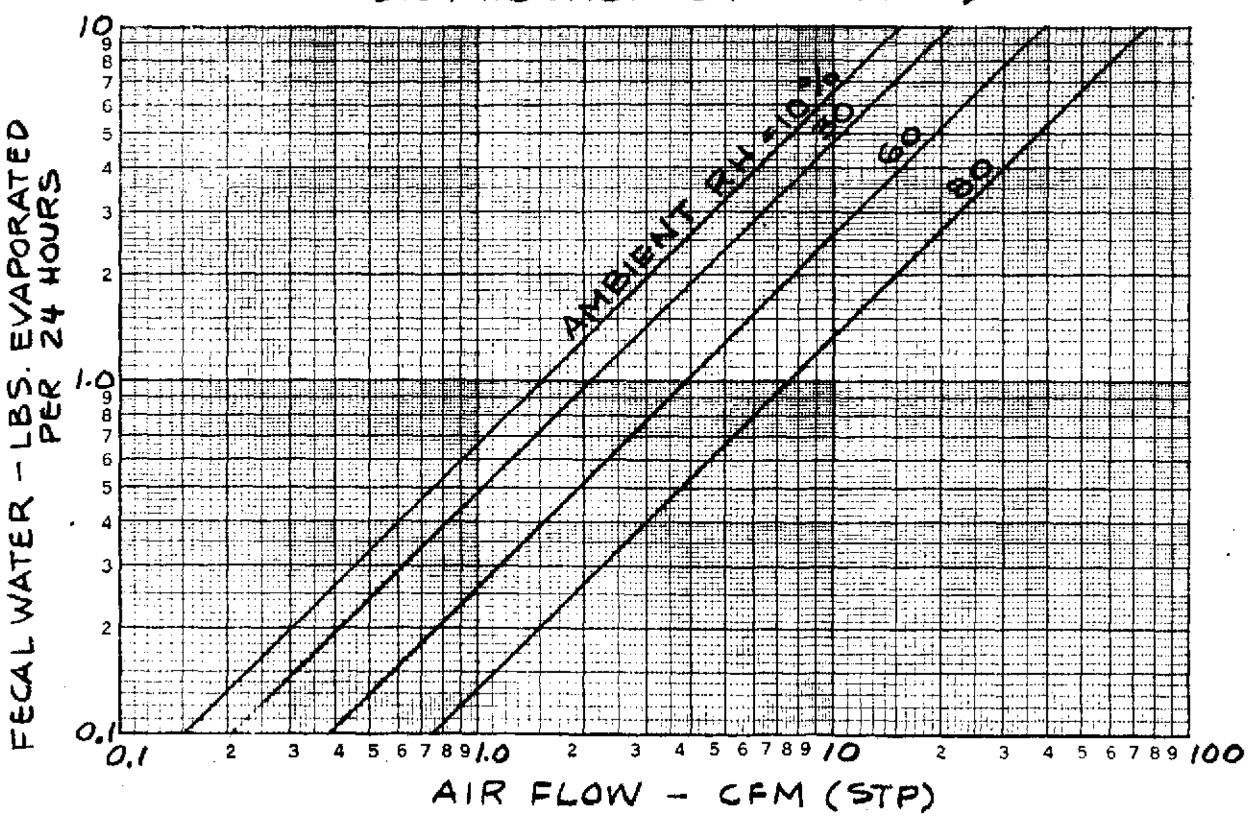


FIGURE 3-8 AIR FLOW REQMTS.

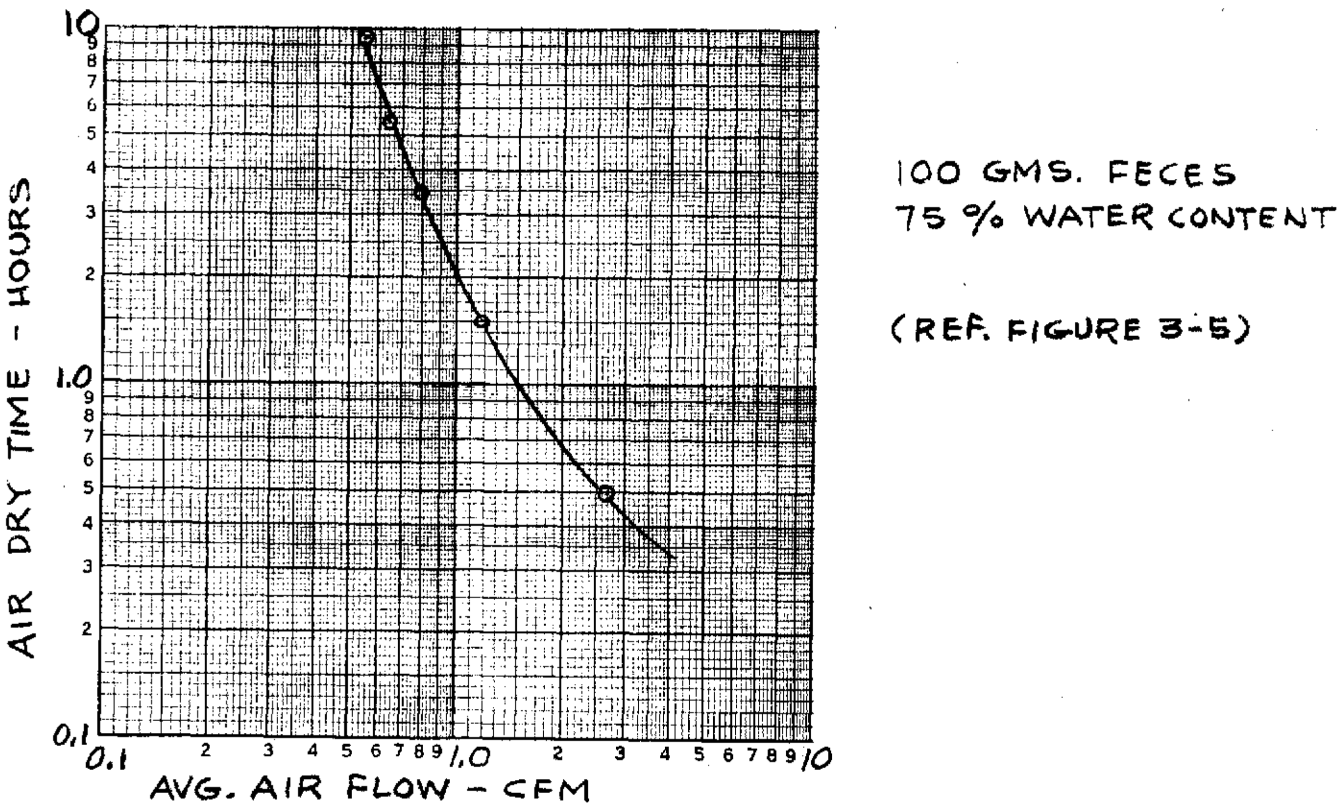


FIGURE 3-9 AVG. AIR FLOW REQUIRED FOR SATURATED EXIT CONDITION

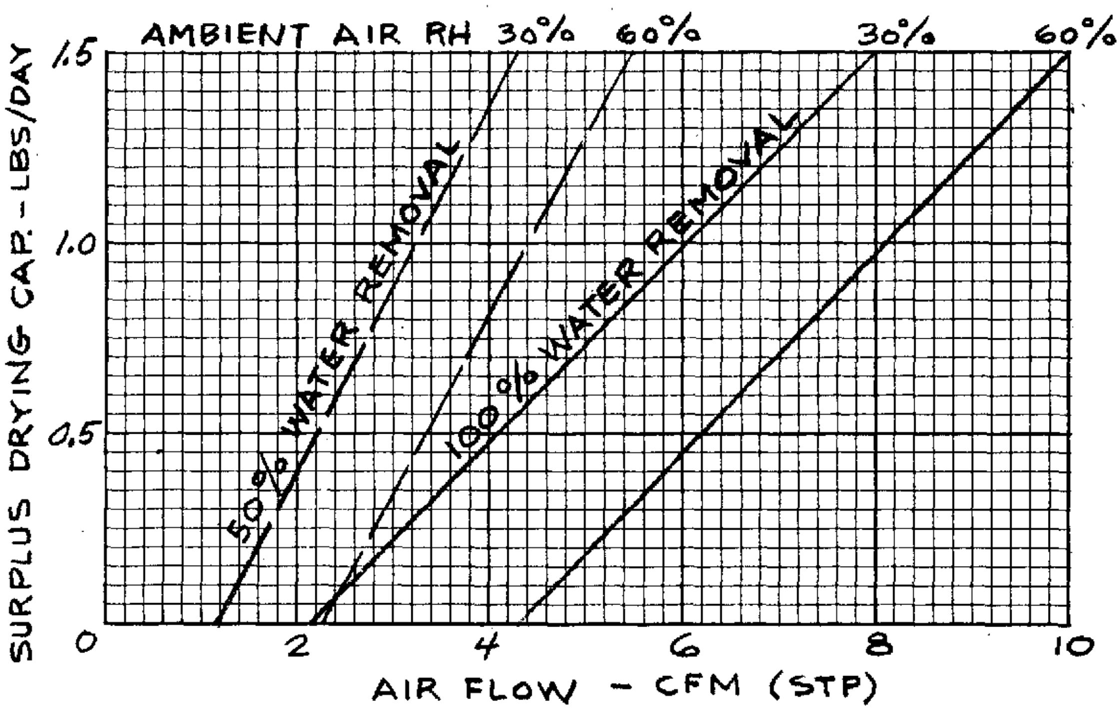


FIGURE 3-10 SURPLUS DRYING CAPABILITY

during the initial portion of the drying cycle. During the latter part of the cycle, the rate of moisture removed will be controlled by the diffusion rate of moisture from the interior to the surface of the fecal particles for subsequent evaporation and removal by the air flow. Thus air flows somewhat higher than the minimum flow rates shown are required.

For average operating conditions, the quantity of fecal water will equal 6(110)0.75/454 = 1.09 lbs/day. Assuming worse case RH conditions, an air flow of about 4.3 CFM is required to evaporate 100% of this quantity of fecal water. Actually, removing 100% of the feces water content is not necessary. Results of a GARD Study on the processing and storage of feces for the Apollo program (GARD Report No. 1276-7374, dated 4/66) indicate removal of 50% of the available moisture by vacuum drying effectively inhibited further microorganism activity for a period of 90 days. No significant difference was found by both anaerobic and aerobic plate counts at dehydration levels from 50 to 99^+ % of the available moisture. On a 50% dehydration basis, an airflow of about 2.1 CFM is required (See Figure 3-8) for 60% RH ambient air (1.13 CFM 30% RH ambient air).

Although an unlikely occurence, the Solids Subsystem must also accommodate vomitus and diarrhetic discharges. Thus surplus drying capability must be available. A normal diarrhetic discharge may vary in volume from about 500 to1200 ml (daily total); vomitus up to 1000 ml. If for the worse case, complete evaporation over two day period is acceptable, a surplus drying capability of 1.32 lbs/day (1200/(454)3) is required. From Figure 3-10, and assuming 60% RH incoming ambient air, an air flow of about 9.4 CFM is required (14.5 CFM if total evaporation in 24 hours is required). Note that the 50% dehydration criteria cannot be applied to vomitus or diarrhea due to their liquid nature.

With such a relatively wide range of air flow requirements, the addition of a humidity level sensor to control air flow (and thus minimize blower power) appears desirable. Located in the storage container, the humidity sensor would "turn-on" the blower whenever the internal RH exceeded 70%. This approach minimizes power input, an important consideration for an actual flight application.

3.1.3 Desiccant Drying

Air drying and desiccant drying of feces are analogous processes. Desiccant drying contains the moisture in a chemical adsorbent rather than dumping to ambient as in air drying. Comparatively, desiccant drying requires the use of additional equipment (i.e., the desiccant canister assembly or equivalent) (Figure 3-11). At the end of the collection cycle, closing the slide valve does not turn off the blower motor; closing the slide valve repositions valve S_1 so that the air within the storage container is continuously recirculated by the blower through the desiccant canister. As with air drying, a humidity sensor can be used to control operation of the blower to minimize power input requirements.

Results of tests (Figure 3-12) using a GE DRY-JOHN prototype model in a test setup simulating the system concept of Figure 3-11 provides drying times comparable to that obtained for air drying (Figures 3.5 and 3-6). As shown in Figure 3-12, 50 percent water removal can be accomplished in as little as 2 hours in the DRY-JOHN system. This is due to the slinger action which results in a greatly increased surface area; this in turn permits rapid drying.

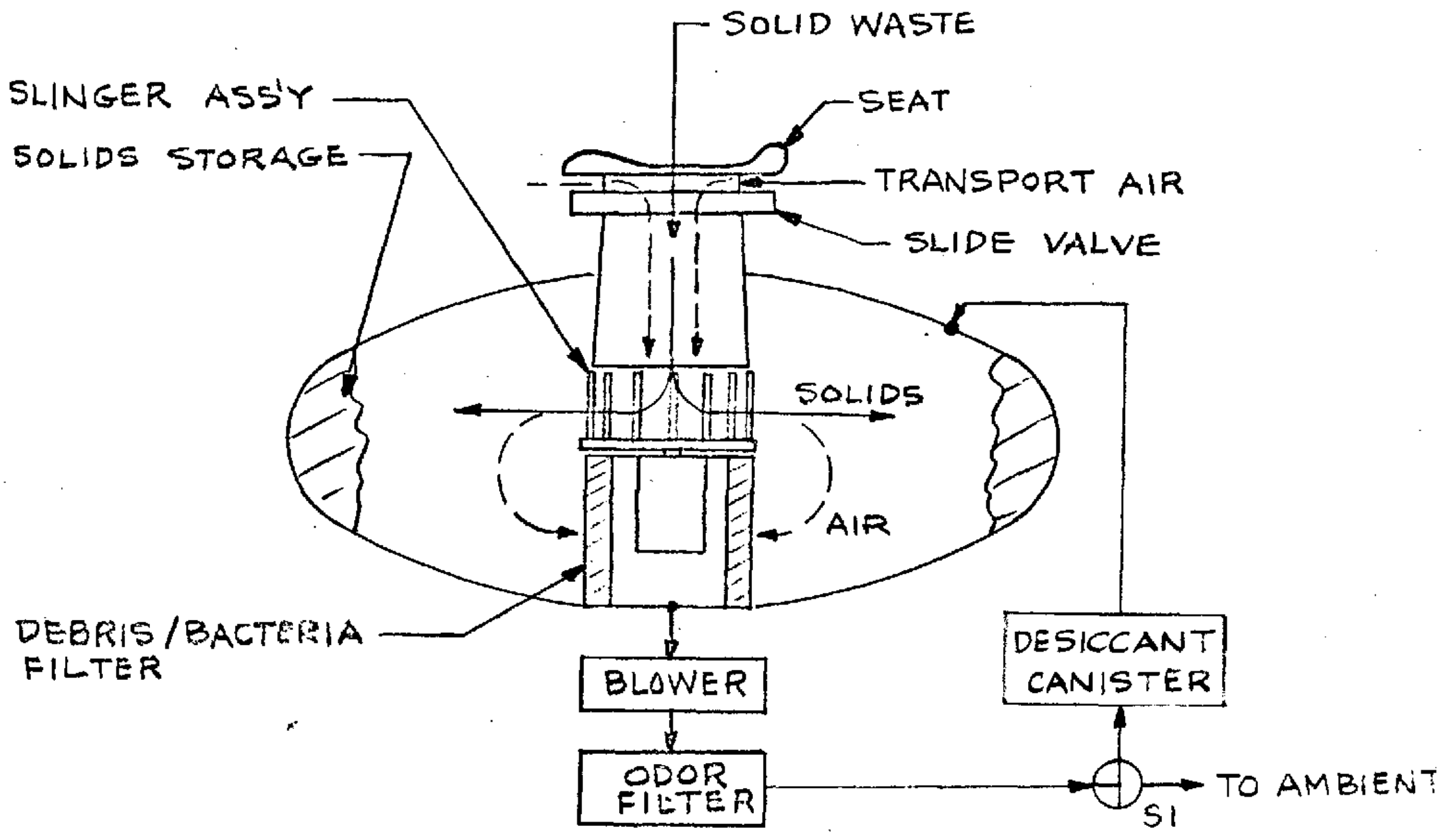


FIGURE 3-11 DESICCANT DRYING CONCEPT

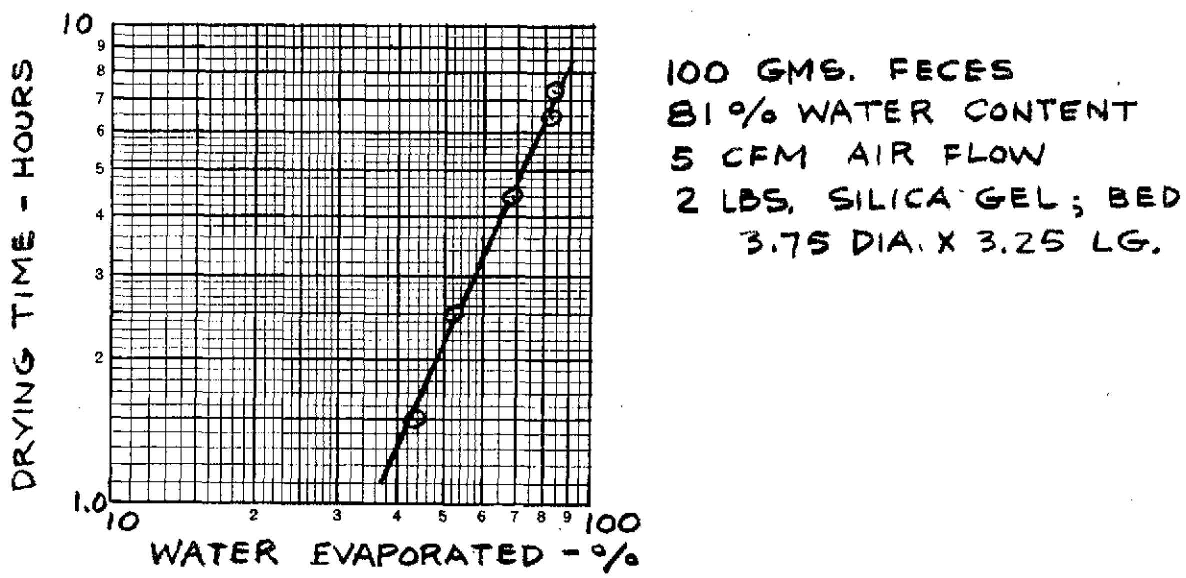


FIGURE 3-12 FECES DRYING USING SILICA GEL

Unlike air or vacuum drying, system weight depends on mission duration. Figure 3-13 shows the amount of desiccant required for two readily available desiccants, i.e., silica gel and molecular sieve. Values shown are for adsorbing fecal water at an average 1.09 lb/day rate, i.e., no diarrhetic discharges, and are based on the adsorbent values shown in Figure 3-14. Note that the weight data are plotted against and end-of-the-mission relative humidity in the storage container. For most of the mission, the air out of the desiccant canister will be at low relative humidity. For silica gel operating at a final relative humidity of 80 percent about 4 pounds of silica gel per day plus container is required.

Several location alternates are available for the dessiccant canister. These alternates involve desiccant location (internal or external to the feces storage container) and desiccant regeneration. Location of the desiccant within the feces container would have the advantage of a continued drying capability in the event of a blower failure. Offsetting this advantage are the mechanical complications of combing desiccant storage within the storage container and the relatively limited internal volume for location of the desiccant.

Even without consideration of vomitus and diarrhetic discharges, desiccant weight requirements for a long duration mission appear prohibitive unless a regeneration capability is added. Figure 3-15 shows this approach. While one canister is adsorbing water vapor, the alternate canister is being regenerated. Regeneration can be accomplished by a submerged electrical resistance heater operating near 250°F. The resulting sterilized steam is vented to the ambient atmosphere via a check valve. At the end of the next collection cycle, the process is repeated but with the canisters in alternate roles.

3.1.4 Disinfectant Addition

Unlike the preceding processing approaches, the addition of a disinfectant does not involve drying the fecal solids. Rather, at the end of each use (collection)cycle, a preset quantity of disinfectant (liquid or powder) is injected into the storage container; see Figure 3-16. Slinger action disperses the disinfectant onto the previously deposited feces. The large surface area of the feces, due to slinger action, alleviates the problem of mixing the disinfectant into the feces. Closing of the slide valve automatically turns off the slinger and blower motors.

Note that although the disinfectant provides for microorganism control (and thus prevents microorganism generation of noxious gases), other noxious gases and vapors must be removed for maximum user acceptance.

The previously noted GARD Study report on the processing and storage of feces for Apollo (GARD Report No. 1276-7374), concluded that a minimum of 8% by weight of MIL-D-51061 (QMC) disinfectant is required to inhibit microorganism metabolic activity (for a period of 45 days and if thoroughly mixed with the feces). MIL-D-51061 is a dry type, phenolic concentrate. Assuming a 100% safety factor to account for poor distribution and mixing, a 6 man crew and average feces output of 110 grams per man-day, then some 104 grams of MIL-D-51061 will be required per mission day. Betadine can be expected to be somewhat more effective. Althought the quantity of disinfectant does not appear to be excessive, data are lacking on the effectiveness of the slinger in distributing the material and consequently the 100% safety factor assumed above may be seriously in error. The larger quantity required for disinfecting of vomitus and diarrhetic discharges is also an added complication.

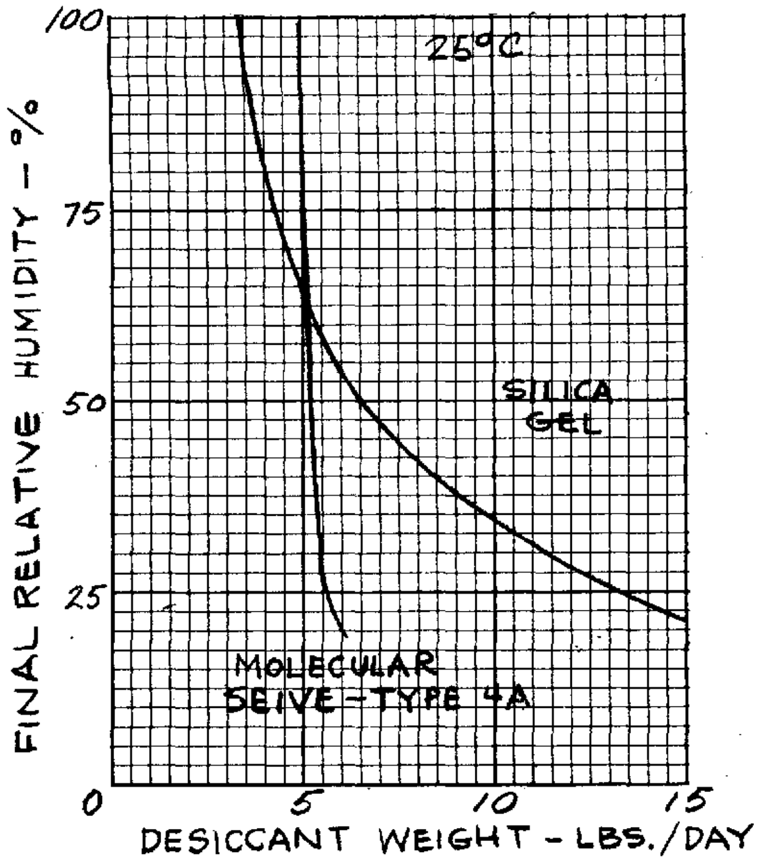
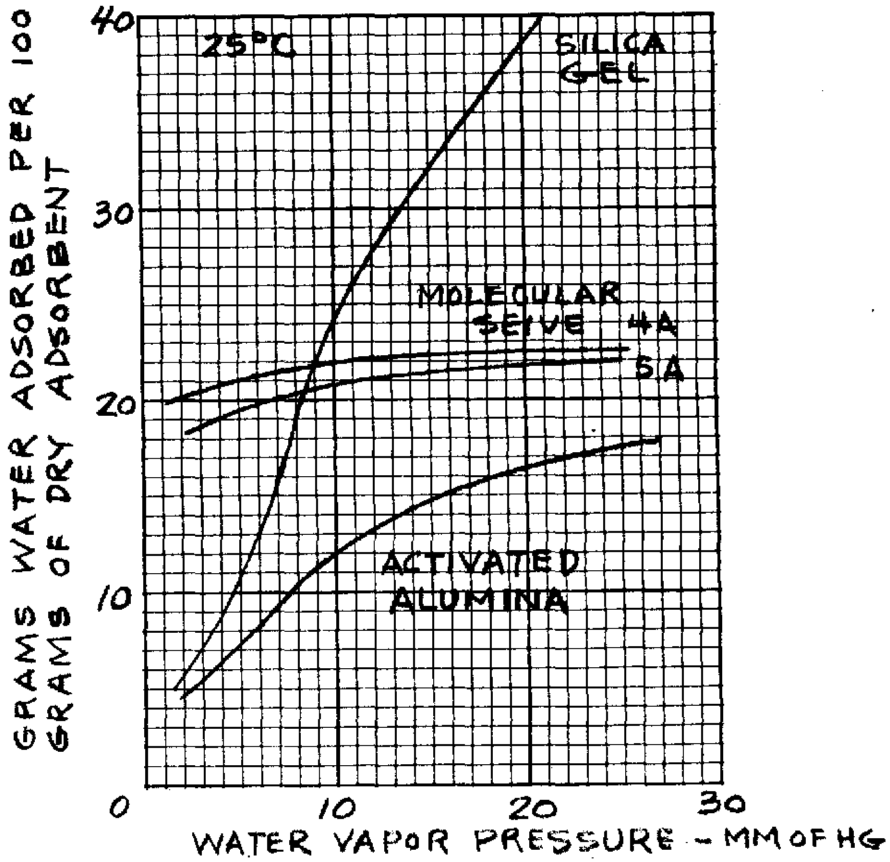


FIGURE 3-13 DESICCANT WEIGHT REQUIREMENTS

FIGURE 3-14 DESICCANT PERFORMANCE



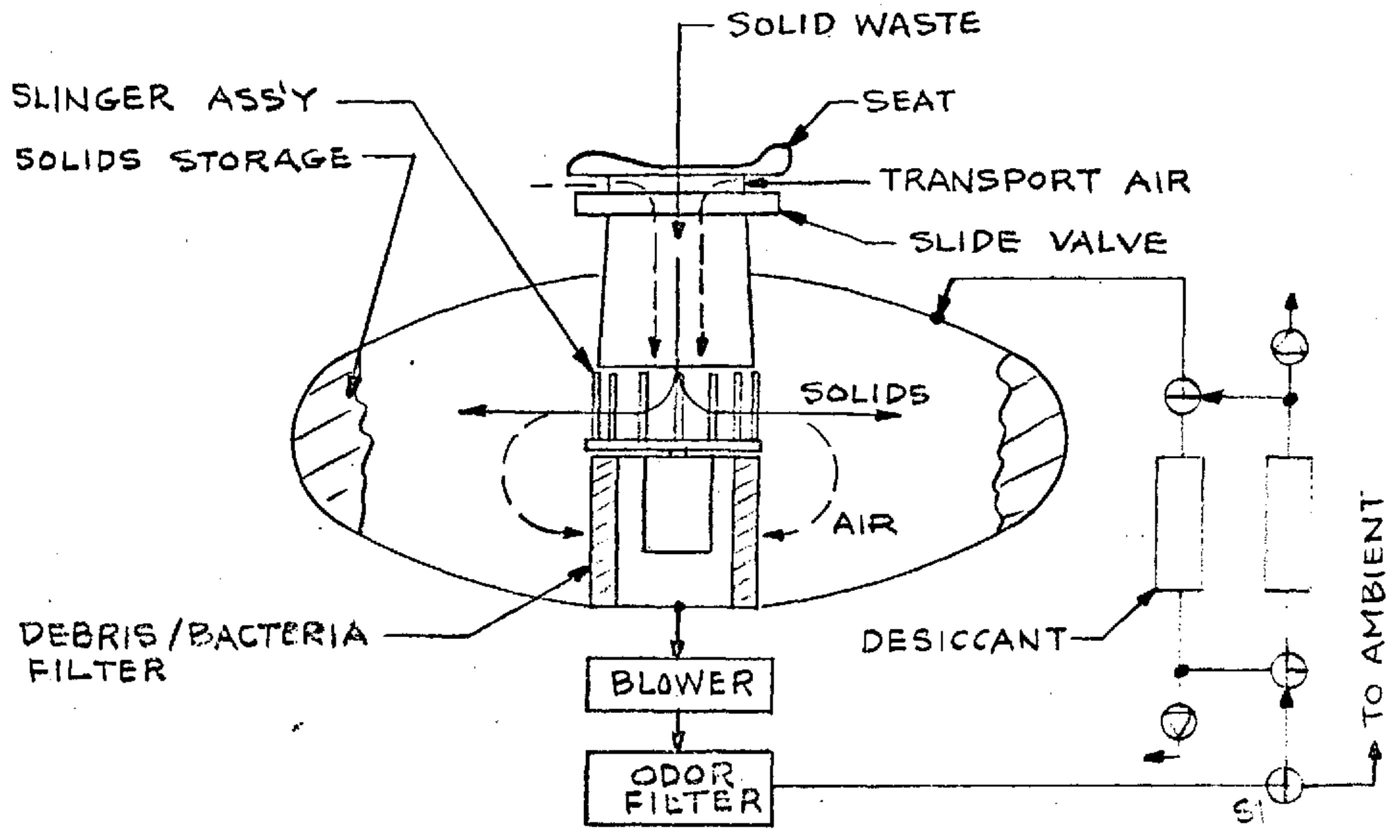


FIGURE 3-15 DESICCANT DRYING (WITH REGENERATION)

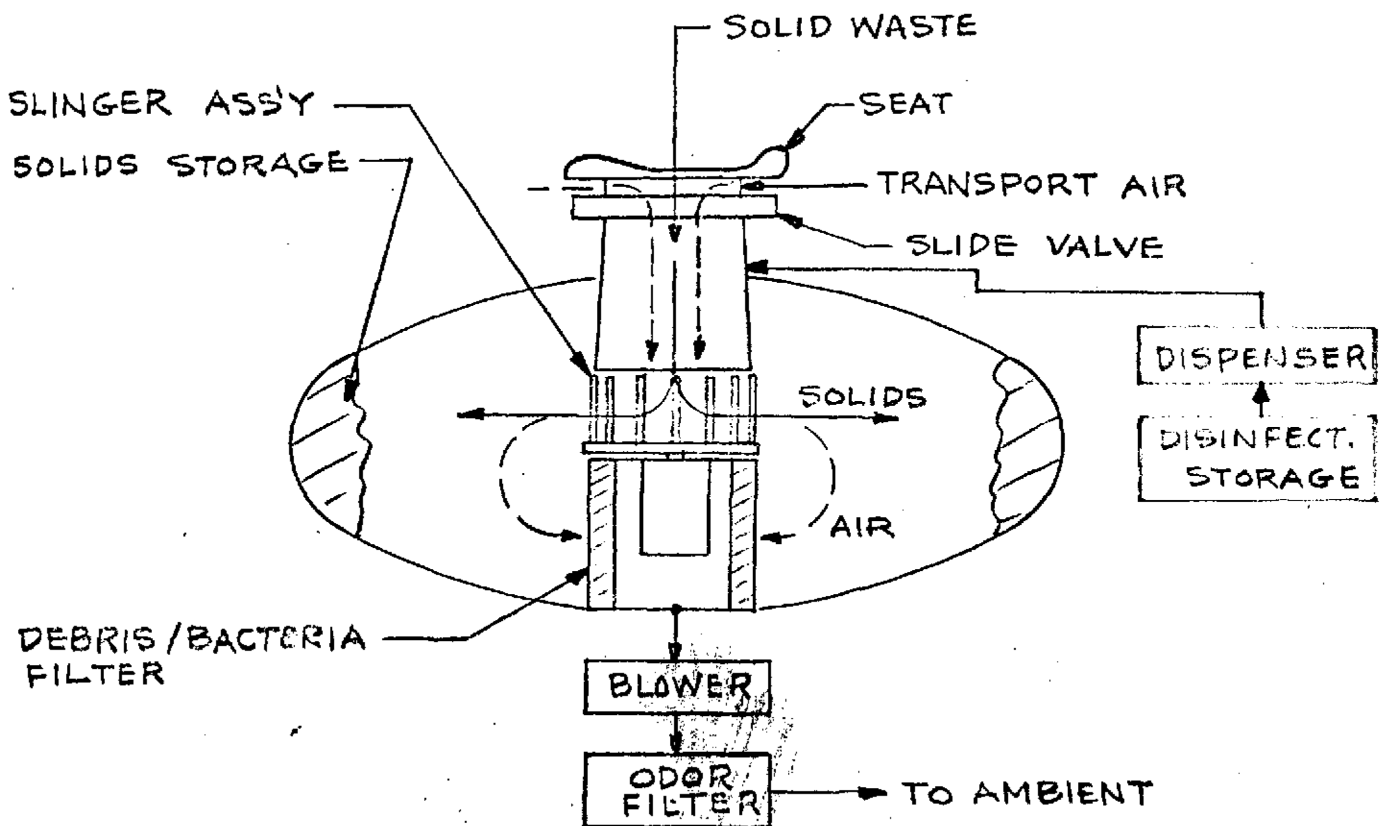


FIGURE 3-16 DISINFECTANT ADDITION CONCEPT

3.1.5 Wet Heat

Figure 3-17 shows the wet heat concept. At the end of the collection cycle, the closing of the slide valve turns off the slinger and blower motors and closes valve S_1.

Between collection cycles, heat is added as required by the thermostat control to maintain the internal environment at about 65°C (150°F). At this temperature, sterilization will not be accomplished; however, microorganism metabolic activity will be inhibited. At the beginning of each collection cycle, slide valve actuation vents the internal pressure through valve S_1 before the slide valve opens. Internal pressure rise is estimated at about 2 psi over ambient, average heat input at about 60 Btu/hour (17.6 watts) depending on losses to ambient.

3.2 Relative Advantage

Table 3.2-1 shows a relative advantage comparison of the fecal microorganism control concepts described above. Based on the comparison criteria and relative weightings shown, either vacuum dry or air dry would appear to be the referred approach.

4.0 Design Criteria for ABSS

For some spacecraft missions, overboard dump of liquids/vapors may be prohibited. This potential operating condition was not considered in the relative advantage comparison above. Although a vacuum pump could be added, with discharge to spacecraft ambient, the vacuum dry concept rating will drop leaving air dry as the preferred concept.

Thus for the ABSS Solids Subsystem, air dry, with humidity level controlled 10 CFM (nominal) blower, is recommended. Under average fecal input and 60% RH ambient air conditions, the blower would operate about 10 hours per day. For 30% RH ambient air, blower operation would be about 5.5 hours/day. For worse case conditions, i.e., 5 average plus one 1200 ml diarrhetic discharge and 60% RH ambient air, about 36 hours is needed. The above times are for 100% removal of the fecal water. Since the blower will only operate (for drying) when the RH in the storage container exceeds a preset value, e.g. 70%, the drying times required will be somewhat less than noted above.

To prevent rapid on-off cycling of the blower, as the collected feces approaches a near dry condition, the relative humidity control should be in series with a time delay. Thus, the blower will always be "on" for a preset time (e.g. 10 minutes) following an "on" input signal from the RH control. Note that the slinger motor must also be operational during drying. This is necessary in that the slinger also provides a phase separator function to prevent particles (solid or liquid) from clogging the filter. Beneficaily, however, the slinger also induces a rotational air flow within the storage container which enhances the drying process.

A factor common to all of the concepts discussed is the necessity of trapping vomitus and disrrhetic discharges in a preferred location within the storage container. Although dried feces, if available, could act as an adsorbent, the addition of an adsorbent material, e.g. Scott foam, within the storage container would appear desirable.

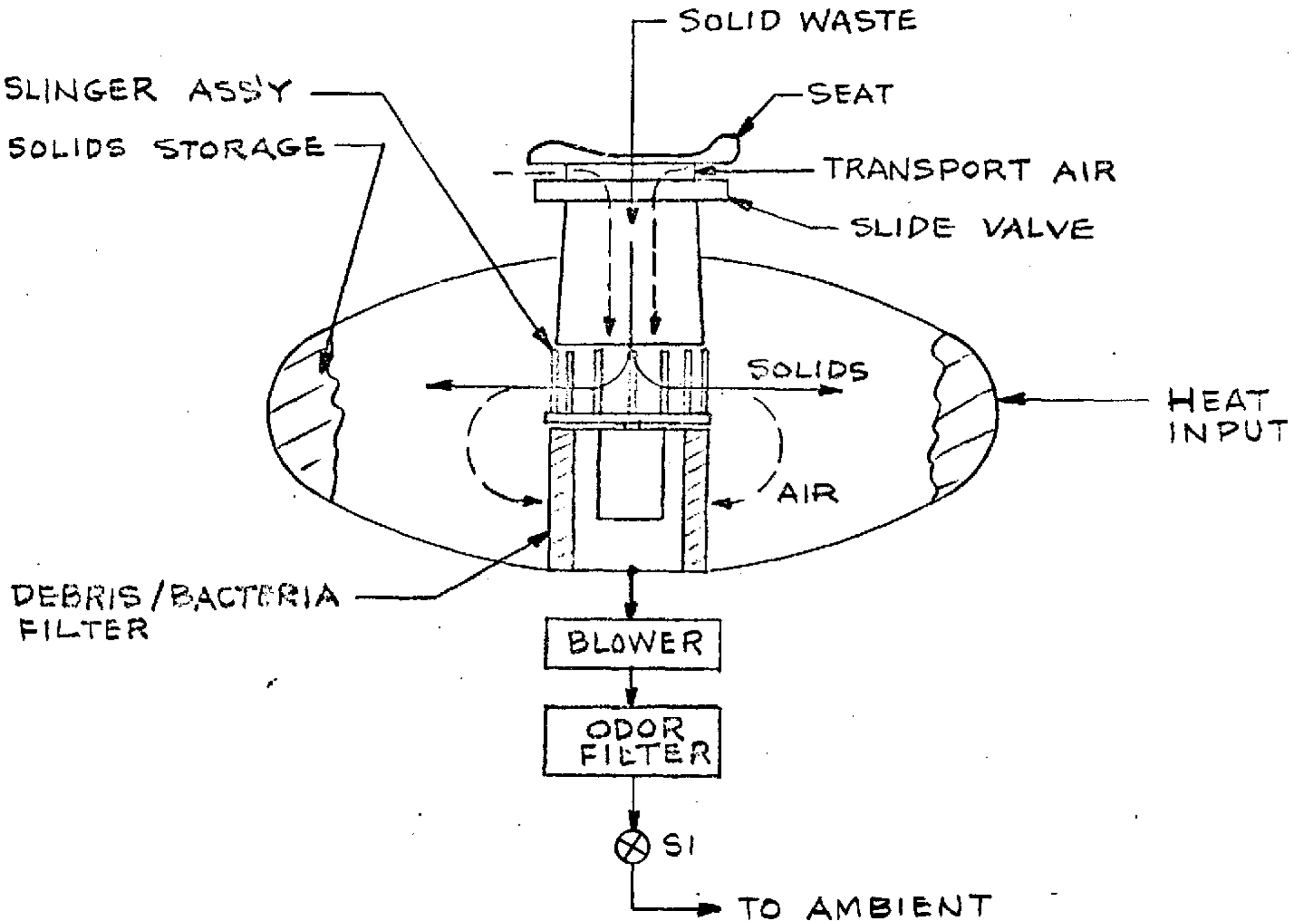


FIGURE 3-17 WET HEAT CONCEPT

TABLE 3.2-1 - RELATIVE ADVANTAGE COMPARISON OF FECAL MICROORGANISM CONTROL CONCEPTS

RELATIVE COMPARISON FACTORS		RELATIVE ADVANTAGE				
CRITERIA*	RELATIVE WEIGHTING	AIR DRY	DESICCANT DRY	DISINFECTANT ADDITION	WET HEAT	VACUUM DRY
Effectiveness	20	5	5	2	3	5
User Acceptance	20	5	5	3	2	5
Safety/Reliability	20	7	5	1	3	4
Operational Flexibility	15	3	3	3	1	5
Development Risk	10	2	2	1	2	3
Size/Weight/Power	15	4	2	3	1	5
Cumulative Advantage	100	26	22	13	12	27

*Criteria Definition (Assume all concepts meeting minimum requirements):

Effectiveness - Relative effectiveness of process in preventing microorganism growth

User Acceptance - Relative esthetic and functional factors

Safety/Reliability - Relative degree of safety, reliability, maintainability

Operational Flexibility - Relative independence from other spacecraft subsystems; alternate operating modes

Development Risk - Relative use of available technology